Appendix F Geology, Soil, Climate and Hydrology Technical Report

Bonneville Power Administration
Kangley – Echo Lake Transmission Project
Geology, Soil, Climate, and Hydrology
Technical Report

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Submitted To:
Bonneville Power Administration
P.O. Box 3621
Portland, Oregon 97208-3621

By:
Shannon & Wilson, Inc.
400 N 34th Street, Suite 100
Seattle, Washington 98103

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Executive Summary

This technical report presents information regarding existing geologic, soil, climatic and hydrologic conditions and natural hazards that could impact or be impacted by construction and operation of one of five proposed electrical transmission line routes. The new transmission line would tap the existing Schultz-Raver No. 2 500-kV transmission line near the community of Kangley. From the tap it would proceed north about 10 miles to the Echo Lake Substation. The route alternatives include options that (1) parallel the existing Raver-Echo Lake 500-kV transmission line, (2) follow a new right-of-way (ROW), and (3) combinations of new ROW and parallel to the existing ROW. We understand that the information provided in this report may be used in part to select a preferred route and to prepare a Draft Environmental Impact Statement.

Chapter 1 of this report presents an overall description of the project, project scope and methods of study. Chapter 2 summarizes the route alternatives and the proposed Echo Lake Substation improvements.

The affected regional environment is discussed in Chapter 3, which includes sections on topography, geology, soils, seismology, hydrology, and wind. In general, the region has moderately rugged topography and is underlain by glacial deposits and by sedimentary and volcanic rock that has been folded and faulted. The affected environment discussion for each of the five route alternatives includes information on major drainages, bedrock and surficial geology, and local topography.

Chapter 4 presents an overview of the resources and natural hazards evaluated, including shallow and deep-seated landslides, soil erosion, settlement, liquefaction, faulting, flooding, and water-quality limited (303[d] listed) water bodies. Each resource was assigned ratings of no, low, moderate, or high impact. Following the overview, Chapter 4 discusses the impacts, mitigation, cumulative impacts and unavoidable effects, irreversible or irretrievable commitments of resources along each of the proposed alternative alignments.

Chapter 6 provides a description of the review and permit requirements related to the resources discussed in this technical report.

Shannon and Wilson, Inc. has included “Important Information About Your Geotechnical Report” (Appendix A) to assist you and others in understanding the use and limitations of our report.

The affixing of the professional seal below indicates the exercise of professional judgement by participation in developing the engineering and geological matters embodied in our work for this project.

SHANNON & WILSON, INC.

Jeffrey R. Laird
Principal Engineering Geologist

Christopher A. Robertson, P.E.
Associate

JRL:CAR:WTL/jrl

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Bonneville Power Administration
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Chapter 1 Introduction

This technical report describes geologic, soil, climatic conditions and hydrologic and natural hazards that are present along the five proposed route alternatives of the Bonneville Power Administration (BPA) Kangley - Echo Lake Transmission Project. It also identifies potential impacts that could result because of construction, operation, and maintenance of the project. The information from this report will be used to prepare portions of an Environmental Impact Statement (EIS) for the proposed project.

1.1 Project Description

The BPA is proposing to build a new 500-kilovolt (kV) transmission line that would connect an existing transmission line (near the community of Kangley) with BPA's existing Echo Lake Substation in King County, Washington. The Vicinity Map, Figure 1, shows the project location. The Project Area Plan, Figure 2, shows the approximate locations of the route alternatives. The new transmission line will be about 10 miles long, depending on the route alternative selected. BPA's primary reason for building the proposed new transmission line is to improve system reliability in the King County area. Under normal growth in demand, system instability could develop as early as the winter of 2002-2003 with an outage of the existing Raver-Echo Lake 500-kV line. Another reason is to enhance the United Sates' delivery of power to Canada as required under the Columbia River Treaty of 1961.

BPA is considering five alternative routes. All routes are east of the existing Raver-Echo Lake 500-kV line that runs between the Raver and Echo Lake Substations, and would cross portions of the Cedar River Municipal Watershed. Once the environmental review is complete, BPA will decide whether and how to proceed with the project. If BPA decides to proceed, construction could begin in 2002.

The proposed project has two major elements, which are:

1. A new 500-kilovolt (kV) transmission line; and
2. An expansion to the existing Echo Lake Substation to accommodate the new transmission line.

Section 2.0 of this report describes the route alternatives and substation improvements that are included in this study. This study consisted of a review of existing data, including reports and aerial photographs, and site reconnaissance along the proposed alternative routes.

Chapter 2 Proposed Action and Alternatives

The proposed new 500-kV transmission line will follow one of five alternative routes that would be on new right-of-way (ROW), east of and next to the existing Raver – Echo Lake 500-kV transmission line, or a combination of these two. The five alternative routes shown on the Project Area Plan, Figure 2, are:

Alternative 1 would be east of and parallel the existing Raver-Echo Lake 500-kV transmission line for its entire length. The new transmission line would tap the Schultz-Raver No. 2 500-kV transmission line about 2.8 miles northeast of the Raver Substation. From the tap, the new line would proceed north-northeast for about 2.9 miles to an existing angle tower, and then continue north for about 6 miles to the Echo Lake Substation. The route would cross the Cedar River about 1.8 miles from the tap. The first 1.2 miles would cross mostly private land and then enter the Cedar River Watershed. It would proceed through the watershed for about 4 miles. After leaving the watershed, the route would cross private residential land, private timberland and State of Washington Department of Natural Resources (DNR) timberland.

Alternative 2 would tap the Schultz-Raver No. 2 line about 1.75 miles east of where Alternative 1 would tap this line and proceed north-northwest to the existing Raver-Echo Lake 500-kV transmission line. From the tap, it would cross private timberland for about 0.6 miles where it would enter the Cedar River Watershed. Alternative 2 would cross the Cedar River about 1.7 miles northeast of the tap and about 0.7 miles east of where Alternative 1 would cross the river. Approximately 3 miles northeast of the tap, Alternative 2 would meet the existing Raver-Echo Lake 500-kV transmission line near an existing angle tower, and then proceed north to the Echo Lake Substation following the same route as Alternative 1.

Alternative 3 would tap the Schultz-Raver No. 2 line about 1.75 miles east of where Alternative 1 would tap this line and proceed north-northwest for about 1.7 miles until it meets Pole Line Road in the Cedar River Watershed. From there the new transmission line would follow Pole Line Road on the southeast side for about 2.0 miles. Then the line would turn northwest and proceed in a straight line to the Echo Lake Substation. After about 0.2 miles from Pole Line Road, the route would cross the Cedar River. Approximately 2 miles northwest of Pole Line Road, the route would leave the Cedar River Watershed. The next 4.4 miles to the Echo Lake Substation would cross mostly private timberland, some DNR timberland, and possibly some private residential land.

Alternatives 4A and 4B would initially follow Alternative 2 and then would proceed west or northwest into the Cedar River Watershed to where they would connect with Alternative 1 before crossing the Cedar River. Both alternatives would then follow the Alternative No. 1 route to the Echo Lake Substation. Alternative 4A would leave the Alternative 2 route after 0.9 miles and join Alternative 1 about 1.6 miles north-northeast of where Alternative 1 would tap the Schultz-Raver No. 2 line. This route segment likely would have one angle about ½-mile northeast of where it leaves the Alternative 2 route. Alternative 4B would leave the Alternative 2 route about 1-1/3 miles north of the tap point of the Schultz-Raver No. 2 line, and then follow

Pole Line Road west to where it intersects Alternative 1. The intersection would be about 1¼-mile north of where Alternative 1 would tap the Schultz-Raver No. 2 line.

The Echo Lake Substation would be expanded to accommodate the proposed new 500-kV transmission line. The Echo Lake Substation improvements will include clearing and leveling an area east of and adjacent to the existing substation. The new substation plan area would be approximately 250 feet in an east-west direction by 750 feet in a north-south direction. The finished surface would be covered with gravel to reduce erosion. While most of the existing substation is in a relatively flat area, the new portion would be on a slope that rises to the east at an average grade of 5 to 10 percent. A cut slope was made on the east side of the existing substation during the original construction. We understand the new construction would require an additional 10- to 15-foot deep cut.

Currently, Road No. 35000 is on the east of the existing substation within the site proposed for the new substation. Therefore, the road would need to be relocated at least 250 feet further east. We estimate that approximately 1500 lineal feet of new road would be required.

2.1 Right-of-Way Clearing

Initially, a strip of land about 150 feet wide would be cleared in the transmission line ROW to allow for tower construction and conductor clearance. Trees would then be allowed to grow to maturity along the outer 35 to 90 feet of the alignment corridor edge. The clearing and regrowth of trees along the edge is to allow the new trees to become established under the new, more open, conditions. Modern logging methods, including the use of cable logging and low ground pressure equipment, would be used to reduce the amount of access road building and ground disturbance.

Disturbance of the soil cover during logging would be reduced using appropriate logging methods. A low ground cover of vegetation consisting of shrubs and grasses will remain following logging and the cleared area would not be burned. Over the years, this vegetation will grow to a taller and denser condition. Consequently, the benefits of vegetation, including root strength, soil cover, interception of precipitation, and evapotranspiration would remain to some extent.

2.2 Transmission Line

BPA proposes to use single-circuit steel lattice towers to support the new transmission line. Typical transmission line tower spacing will be about 1,100 to 1,200 feet, except where longer spans are required to cross streams such as the Raging River and the Cedar River. The exact tower locations would be determined after the preferred alternative is selected.

Stable foundations for the transmission line towers and substations are necessary to reduce the potential for structure failures. The towers and their foundations would be designed and constructed to withstand the structural dead loads and live loads from wind and earthquakes.

Site investigations should be conducted to evaluate subsurface conditions so that adequate foundations can be designed and constructed.

In general, foundations would consist of steel plates that are buried in excavations averaging 15 feet deep. Soil would be backfilled and compacted over the plates. Where soil depths are shallow and hard or massive rock is encountered, the towers would be anchored to the rock using rock dowels.

In general, the proposed tower locations do not include areas of deep, soft ground where settlement and liquefaction are concerns; unstable slopes in streams or other water bodies; or floodplains. Therefore, special foundations, such as driven piles, drilled concrete piers, or soil anchors should not be required.

2.3 Access Roads

BPA normally acquires rights and develops and maintains permanent access for travel by wheeled vehicles to each structure. Access roads are designed for use by cranes, excavators, supply trucks, boom trucks, and line trucks for construction, ROW clearing, and maintenance of the transmission line. BPA prefers road grades of 6 percent or less in areas of highly erodible soils and 10 percent or less for erosion resistant soils. For short distances, maximum acceptable road gradients are 15 percent for trunk or main roads and 18 percent for spur roads (roads that go to each structure if the structure is not on a trunk road). The locations and lengths of new trunk and spur access roads that would be required for each Alternative have not yet been determined. These will be determined after a preferred alternative is selected.

Best Management Practices (BMPs) are used in constructing and upgrading access roads, as described in Section 4. New or existing trunk access roads are surfaced with gravel for construction and maintenance activities. Water bars are usually installed on trunk roads after construction. Trunk and spur access roads are revegetated after construction.

Regardless of the alternative selected, much of the new transmission line could be built using the existing access road system owned by King County, Seattle Public Utilities (SPU), private timber company and BPA. This existing system includes trunk and spur logging roads, trunk and spur access roads for the Cedar River Watershed, and farm and residential roads to the communities of Kangley, Selleck, and Halmar Gates.

New trunk roads may be required depending on the alternative selected. Easements for new trunk roads built outside the ROW would be 50 feet wide. New or existing trunk roads would be graded to provide a 14-foot wide travel surface, with an additional 4 to 6 feet on curves. About 10 feet on both sides of a trunk road would be graded for ditches, etc., for a total clearing width of 24 to 30 feet. The road surface is usually surfaced with gravel for construction and maintenance activities.

New spur roads will be required to access most tower locations. Spur roads would be built within the ROW from the on-ROW trunk roads to access structures.

Chapter 3 Affected Environment

The topography, geology, and soils of the project area are key factors that affect the susceptibility of different areas to erosion and sedimentation. Erosion and sedimentation can cause degradation of water quality and affect fisheries and other habitat. Landslides, soil creep and other mass wasting processes can contribute to hillslope erosion and stream sedimentation. Logging, ROW clearing, road and tower construction, use, and maintenance can affect these processes. The following sections describe the topography, geology, and soil types present within the project area.

3.1 Topography

The project area can be subdivided into two physiographic provinces: a southern lowland area in Green Valley and a northern mountainous area, which includes Taylor Mountain, Brew Hill, Rattlesnake Mountain, and the intervening Raging River valley (Rosengreen, 1965). As described in Section 3.2, Geology, both areas are underlain by glacial drift. Bedrock outcrops are limited almost entirely to the northern mountainous area. The Geologic Map, Figure 3, shows topographic contours and the locations of the surficial bedrock and glacial units in the project area. The Slope Map, Figure 4, shows areas with slopes between 0 and 15 percent, 15 and 40 percent, 40 and 65 percent, and steeper than 65 percent.

The southern lowland area consists of a series of glaciofluvial terraces that are cut by abandoned, Vashon Stade glacial meltwater channels and more recent streams, including the Cedar River and other smaller streams, such as Taylor, Williams and Steele Creeks. The terraces consist of nearly flat to rolling drift plain with low elongated ridges that typically have less than 200 feet of relief. In the project area, the terraces range in elevation from 800 feet near the Cedar River to about 1,000 feet adjacent to the northern mountainous area. The terraces are somewhat higher in elevation to the south, rising to about 1,600 feet 1 mile southeast of the project area. An area of complex topography is present on the western edge of the project area between the Cedar River to the south and the northern mountainous area to the north. This area includes several small lakes, bogs and sinks that were formed by outwash sediment deposited around stagnant ice that remained after the glacier had retreated.

The Cedar River is the principal stream in the southern lowland area. Its headwaters are east and southeast of the project area and the river flows generally northwest to Renton, where it discharges into Lake Washington. The Cedar River enters the east side of the project area at about elevation 880 feet and leaves the western edge of the project area at about elevation 700 feet. It has an average gradient of about 38 feet per mile (0.7 percent). The Cedar River and other streams have incised into the glaciofluvial terraces, locally exposing older glacial deposits and bedrock, and creating steep-walled gorges. The Cedar River floodplain in the study area is narrow, but does contain lateral and center channel gravel bars.

The northern mountainous area consists of relatively low rounded mountains with moderate slopes and intervening valleys. The Vashon Stade continental glacier overrode almost the entire area, eroding the mountains and depositing a mantle of glacial till and outwash. At the maximum glacial stand, only the highest points of Rattlesnake Mountain emerged above the glacial ice. Rattlesnake Mountain is the highest point adjacent to the project area, with a summit elevation of 3,517 feet.

The Raging River is the principal stream in the northern mountainous area. It flows north through a broad, glacially carved, U-shaped valley between Brew Hill and Taylor Mountain to the west and Rattlesnake Mountain to the east. The head of this U-shaped valley forms a broad pass between the Cedar River to the south and the Raging River to the north at about elevation 1,500 feet. The upper reaches of the Raging River are moderately incised into the U-shaped valley. Near the end of an old railroad grade at Kerriston, the Raging River becomes more deeply incised, with steep valley walls as high as 200 feet. Several smaller streams drain to the south into the Cedar River, including Rock, Williams, and Steele Creeks. These streams typically are deeply incised except where they cross gently sloping terraces of the southern lowland area.

3.2 Geology

The project area is located along the western margin of the South Cascade Range (Galster and others, 1989). The South Cascades are composed primarily of Tertiary age volcanic, volcaniclastic and associated sedimentary rocks. These rock units have been folded and faulted since they were deposited. Repeated advances of continental glacial ice sheets into the Puget Sound lowlands during the Quaternary have eroded the Cascade foothills and deposited thick sequences of glacial sediments. The geology along the alternative alignments is shown on the Geologic Map (see Figure 3). Table 1 presents descriptions of the geologic units that are present along the alternative alignments. The map and descriptions of the geologic units are based on published geologic maps, and on the aerial photographic mapping and ground verification described in Section 7.0.

3.2.1 Tertiary Geology of the Project Area

The Tertiary age rocks that are exposed in the project area have been subdivided into a group and several formations. The following paragraphs describe each rock unit from oldest to youngest.

The oldest rocks exposed in the project area are the late early to middle Eocene (43 to 54 million years before present {mybp}) rocks of the Raging River Formation (Vine, 1962). These rocks are an estimated 3,000 feet thick and consist of volcanic sandstone, siltstone and conglomerate that were deposited in a nearshore marine environment. Frizzell and others (1984) show one area where the Raging River Formation outcrops in the project area in Section 14, about one mile southwest of the Echo Lake Substation (Unit Trr on Figure 3).

Nonmarine volcanic and sedimentary rocks of the 11,000-foot thick, middle to late Eocene Puget Group conformably overlie the Raging River Formation (Frizzell and others, 1984).

These rocks were deposited primarily in fluvial environments and to a lesser extent in nearshore marine environments. The rocks include sandstone, siltstone, claystone and coal. The sandstone is generally massive to cross bedded, with occasional channel cut-and-fill structures. The Puget Group has locally been divided into several formations, which include from oldest to youngest, the Tiger Mountain, Tukwila, and Renton Formations. The following paragraphs describe each of these formations. Numerous outcrops of the Puget Group that have not been differentiated into formations are present within the project area north of the Cedar River (Unit Tpg on Figure 3).

The late early to middle Eocene (43 to 54 mybp), 2,000-foot thick, Tiger Mountain Formation consists of medium-grained sandstone with interbedded siltstone, conglomerate and coal beds (Vine, 1962). Clay minerals represent about 10 percent of the rock volume and provide the matrix in these clastic rocks. The Tiger Mountain Formation outcrops along the north half of the Alternative 1 alignment (Unit Tptm on Figure 3).

The upper portion of the Tiger Mountain Formation is interbedded with volcanic rocks of the conformably overlying Tukwila Formation (Vine, 1962). The middle to late Eocene (36 to 50 mybp) Tukwila Formation is composed of volcanic lava flows, sills and dikes, breccia, conglomerate and sandstone. Volcanic tuff and breccia probably makes up most of the Tukwila Formation, but the volcanic flow rocks are more resistant to erosion, thereby forming much of the visible outcrop. Tukwila Formation rocks are exposed along the west flank of Rattlesnake Mountain, east of the Alternative 3 alignment, and along the north side of the Cedar River across the Alternative 3 alignment (Unit Tpt on Figure 3).

The youngest rocks in the Puget Group, the late Eocene Renton Formation (Vine, 1962) conformably overlie the Tukwila Formation. The Renton Formation is as thick as 2,250 feet and consists of sandstone, siltstone, claystone and coal. This formation was deposited in fluvial and nearshore marine environments. Clay commonly cements the sandstone. Fine-grained, interbedded siltstone and claystone commonly form valleys between more resistant sandstone ridges. Renton Formation outcrops just to the west of the approximate center of the Alternative 1 alignment (Unit Tpr on Figure 3). Historic coal workings exist in the Renton Formation on the south flank of Brew Hill, west of the Alternative 1 alignment (Walsh, 1984).

Volcanic rocks of the late Oligocene (25 to 35 mybp) Huckleberry Mountain Formation unconformably overlie the older Puget Group and Raging River Formation. These rocks consist of generally well-bedded andesite and basalt breccia, tuff and lava flows with minor amounts of volcanic sandstone, siltstone and conglomerate. Huckleberry Mountain Formation outcrops more than 1.2 mile south of the Pole Line Road portion of section Alternative 3 and south of where Alternatives 2 and 3 would tap the Schulz-Raver No. 2 line (Unit Thm on Figure 3). These rocks probably would not be encountered during construction and maintenance of either Alternative 2 or 3.

The youngest rocks exposed in the project area consist of igneous intrusions into Puget Group rocks. Frizzell and others (1984) describe two outcrops of intrusive rock. Diabase and gabbro (Unit Tdg on Sheet 3 of Figure 3), which are dark-colored, igneous intrusive rocks, form the resistant ridge west of Alternative 1, 3,000 to 4,000 feet north of where it would tap the

Schulz-Raver No. 2 line. The second outcrop consists of early to middle Miocene (18 to 25 mybp) tonalite (Unit Tit on Sheet 1 of Figure 3), which is an igneous intrusive rock similar in appearance to granite. This outcrop is located about 2.4 miles south of the Echo Lake Substation and 1,000 feet west of Alternative 1. It is possible that these rocks would be encountered during construction and maintenance of Alternative 1.

3.2.2 Quaternary Geology of the Project Area

Geologic processes profoundly influenced the surficial deposits and landforms in the project area during the Quaternary Period (present to 2 mybp). With the exception of the highest portions of Rattlesnake Mountain, the entire project area was overridden by continental glacial ice during the Pleistocene Epoch 10,000 years ago to 2 mybp. The continental glacier deposited variable thicknesses of glacial till and glacial outwash in the northern mountainous area. In the southern lowland area, the glaciers deposited extensive glaciofluvial and ice-contact deposits, and reshaped the surface with a series of meltwater channels that formed beneath and in front of the ice sheet and as the continental glacial ice retreated. Following glacial retreat, the landforms were locally modified by fluvial erosion and deposition and mass wasting.

3.2.2.1 Pleistocene Glacial Geology

At least six periods of continental glaciation have been documented in the Puget Lowland and adjacent margins of the Cascade and Olympic Mountain Ranges. However, evidence of only the most recent period, termed the Vashon Stade (which occurred between 15,000 and 13,500 years ago in the central part of the lowland), has been described in the project area (Rosengreen, 1965). Each advance and retreat of an ice sheet may be characterized by a complex sequence of glaciolacustrine sediments, glaciomarine drift, advance outwash, till and recessional outwash. Erosion and deposition of the glacial sediments between each glacial interval have altered these deposits. The total thickness of these Pleistocene deposits can range between 0 and 3,700 feet in the Puget Lowland.

During the Vashon Stade of the Fraser Glaciation, the Puget lobe of the glacier flowed southeast across the northern mountainous area, covering and reshaping all but the highest points of Rattlesnake Mountain. The upper limits of ice can be determined from the highest presence of glacial till and erratic boulders. The glaciers advanced across the southern lowland area, terminating against mountains south of Green Valley. As the glaciers advanced over the area, they eroded the underlying bedrock, shaping streamlined, molded forms. A mantle of lodgment till (Unit Qvt on Figure 3), which consists of subangular to rounded gravel-, cobble- and boulder-sized clasts supported in a matrix of dense silt and sand, was deposited at the base of the glacier. Lodgment till is the most prevalent Quaternary deposit in the northern half of the project area along Alternative 1 and 3 alignments (Unit Qvt on Figure 3).

The glacier blocked the Snoqualmie and Cedar Rivers, diverting the drainage along the eastern ice margin. Meltwater from these drainages flowed along the margin of the ice, south of the current Cedar River, until it entered the valley currently occupied by Taylor Creek. It flowed southeast to Eagle Gorge, and then flowed northwest down the Green River to Kankaskat. From Kankaskat, meltwater continued south along the ice margin against the western Cascade foothills. Ultimately the meltwater reached the Chehalis Valley, which was the principal outflow channel beyond the glacier terminus. At the maximum stand, ice-contact deposits, consisting of stratified sand and gravel, silt, clay and glacial till were deposited along the glacial margin. Stagnant ice that was covered with ice-contact deposits subsequently melted causing collapse features such as kettles. Ice-contact deposits are widespread along the west and south slopes of Taylor Mountain. Alternative 1 crosses ice-contact deposits north of the Cedar River (Unit Qvi on Figure 3).

As the glacier receded, a series of meltwater channels developed as the ice front successively moved to the northwest. Meltwater streams deposited recessional outwash consisting of stratified sand and gravel. Rosengreen (1965) describes seven stages of the recessional history. The geologic map by Frizzell and others (1984) includes numbering of these stages, with 1 being the oldest (e.g., unit Qvr1 on Figure 3). Several of these stages occur in the project area as successive outwash terraces that formed as meltwater channels incised into previous terraces and successive deposits of ice-contact sediments. Glacial lakes formed periodically along the Raging River, dammed by the ice margin to the north. Rosengreen (1965) describes glaciolacustrine deposits near Kerriston, and west of the Echo Lake Substation. The glaciolacustrine deposits consist of well-stratified sand and silt, with a few thin lenses of gravel. These glaciolacustrine deposits typically have a limited aerial extent. As such, they are not included in the geologic mapping by Frizzell and others (1984), and are not represented on Figure 3 or on Table 1.

3.2.2.2 Holocene Geology

Holocene deposits include landslides, colluvium, bogs, alluvium, and volcanic ash. Landslide deposits result from the relatively rapid downslope movement of rock and soil, and are generally found on and at the base of hillslopes. They usually consist of a remolded, heterogeneous mixture of several soil types and commonly include organic debris. Frizzell and others (1984) describe a large, ancient, deep-seated landslide complex in the approximate center of the Alternative 1 alignment (Unit Qls on Figure 3). As described in the following section, landslides are relatively uncommon in the project area.

Colluvium is soil that has been transported downslope, generally by mass wasting processes, including shallow landsliding, rainsplash erosion, and soil creep. It generally develops on slopes and near the base of a slope. The thickness can range from a few inches to 10 feet or more, with the thickness usually increasing downslope. Colluvium is relatively widespread in the study area, as described in Section 3.3; however, the unit is generally not shown on geologic maps because it is relatively thin.

Bog deposits include peat and organic with lacustrine deposits (Unit Qb on Figure 3). They occur in poorly drained, low-lying areas, such as the broad pass near Halmar Gate, and in areas where stagnant ice was present, such as the ponds and sinkholes north of the Cedar River and east of Alternative 1. Bog deposits typically are in areas currently designated as wetlands can provide poor foundation conditions.

Rivers and streams deposited alluvial sediments in and adjacent to current and historical channels. Alluvium includes fine-grained, overbank deposits and coarse-grained channel deposits. Older alluvial deposits are present along the Cedar River in the form of low, discontinuous terraces (Qa on Figure 3) that were deposited after the continental glaciers had fully retreated. The terraces formed as the Cedar River eroded and incised a deeper channel, leaving remnants of the alluvial deposits along the valley sides. The alluvium consists of medium dense, moderately well sorted, cobble and gravel deposits. Recent alluvial deposits occur in and adjacent to the streams and rivers in the project area in the forms of sand, gravel and cobble bars, and alluvial fans.

Volcanic ash was widely deposited over most of western Washington as a result of the catastrophic eruption of Mount Mazama in southern Oregon approximately 6,600 years ago and other less extensive volcanic eruptions. The deposits are well preserved in bog deposits. Elsewhere, they typically are mixed with other soil types.

3.2.2.3 Landslides

Few landslides are identified in the published geologic maps of the project area. We did not identify landslides during our field reconnaissance or photogeologic studies that were not already identified in published literature. The paucity of landslides is probably due to the relatively gentle to moderate slopes, and relatively stable geologic conditions.

Deep-seated landslides can range in depth from 10 feet to more than 100 feet and may involve movement of bedrock and soil. Deep-seated landslides generally initiate as a single mass movement that may then separate into discrete blocks. Typically, deep-seated landslides have a zone of weakness, such as a layer of clay or weak rock, where a landslide slip surface forms. Landslide movement is usually initiated by:

- Excessive pore water pressure in the landslide mass, such as during wet storm periods.
- Removing support from the toe of the landslide by stream erosion or excavation for a road or other feature.
- An increase of driving forces at the top of the landslide. Typically, this occurs when a fill is placed on the slope for construction of a road or other structure.
- Strong ground motions during an earthquake. The large, ancient deep-seated landslide on the Alternative 1 alignment may have been initiated during a large-magnitude earthquake.

Shallow landslides are normally less than 10 feet deep and occur in soil and highly weathered bedrock. Shallow landslides typically occur on slopes that are steeper than 65 percent (33 degrees), although they can occur on much flatter slopes under certain conditions. Shallow landslides usually occur during periods of intense and/or prolonged precipitation. Other factors that contribute to shallow landslides include changes that tend to increase the steepness of a slope, such as erosion or excavation of soil at the toe of the slope or placing fill on a slope. Poorly compacted road fills are particularly susceptible to shallow landsliding. Stormwater runoff that discharges as concentrated flow on a slope can contribute to instability both by causing erosion that oversteepens a slope and by increasing the pore water pressure in the slope soils.

3.2.3 Geologic Structure

The geologic structure of the project area is dominated by a broad zone of northwest-southeast trending faults and folds that comprise the Olympic-Wallowa Lineament (Frizzell and others, 1984). The once near-horizontally bedded, sedimentary rocks have been uplifted and folded, tilting the bedded rock in various directions and at various angles. Two major folds are present in the project area, the Rattlesnake Mountain syncline and the Raging River anticline, as shown on the Geologic Map, Figure 3. A syncline is a fold where the rock layers dip towards the axis or center of the fold. The surface of a rock layer in a synclinal fold forms a concave-upward surface. An anticline is the opposite of a syncline. That is, the rock layers dip away from the axis of the fold, such that rock layers form convex-upward surfaces. The axis of the Raging River anticline follows the Raging River Valley south to just west of Brew Hill. In general, rock layers west of the Raging River dip down to the west and southwest at angles of 25 to 50 degrees. East of the Raging River, rock layers generally dip down to the east and southeast at angles of 30 to 60 degrees. The axis of the Rattlesnake Mountain syncline is east of the project area on the east flank of Rattlesnake Mountain. Rock layers east of the synclinal fold axis dip down 60 to 65 degrees to the west.

Previous workers have mapped several faults in and adjacent to the project area (Frizzell and others, 1984; Phillips; 1984; and Walsh, 1984). These faults generally trend northwest to north-northwest. The fault planes are apparently high angle, and most displacement is vertical. From east to west, these include the Rattlesnake Mountain, Raging River, and Piling Creek Faults, as shown on Figure 3. The Piling Creek Fault is the southeastern extension of the Hobart Fault. The age of the faulting is uncertain; however, Gower and others (1985) found that movement on the Rattlesnake Mountain and Piling Creek Faults is not older than the Miocene – Oligocene boundary (24 mybp). Gower and others (1985) do not present information regarding the age of the Raging River Fault. There is no published evidence of recent movement on these faults or that these faults offset Pleistocene or Holocene sediments.

The Rattlesnake Mountain fault is located east of the project area, mostly on the east flank of Rattlesnake Mountain. The fault movement has displaced Tiger Mountain Formation rocks down to the east and against younger Oligocene Rattlesnake volcanic rocks. North of the Cedar River, Alternative 3 is subparallel to and about 5,000 to 8,000 feet east of this fault. The Echo Lake Substation is about 7,500 feet east of the fault. We did not observe evidence of surface expression of this fault during our field visits.

The Raging River Fault is mostly concealed in the project area. Its trace is interpreted based on rock units exposed north-northwest of Preston, about 1.5 miles northwest of the Echo Lake Substation, and near Steele Creek northeast of Lookout Mountain. Near Steele Creek, the fault juxtaposes undifferentiated Puget Group volcanic rocks to the west against Tiger Mountain Formation rocks to the east. The relative direction of movement is unknown. The southeastern projection of the fault would cross Alternative 3 at the Cedar River. North of the Cedar River, the inferred fault trace diverges from the Alternative 3 alignment until it is about 6,000 feet to the east of the Echo Lake Substation. The Alternative 1 alignment crosses the inferred fault trace about 1,000 feet south of the Raging River. We did not observe evidence of surface expression of this fault during our field visits.

The Piling Creek Fault and its northwestern extension, the Hobart Fault, is inferred through the project area based on exposures 5 to 6 miles northwest and 7 to 8 miles southeast of Selleck. The southeastern extension of the fault has three splays. Assuming the interpreted fault trace is correct, it would cross Alternative 1 about 2,500 feet north of the Cedar River, Alternative 2 at the Cedar River, and Alternative 3 about 1 mile north of the tap with the Schultz-Raver No. 2 line. The fault offset is down to the northeast. We did not observe evidence of surface expression of this fault during our field visits.

3.3 Soils

The soils in the project area have characteristics that are typical of the western Cascades of Washington. The soil characteristic that is most relevant to this study is the erodibility. The Soil Map, Figure 5, is based on soil maps published by the National Resource Conservation Service (NRCS), formerly the Soil Conservation Service (1992). Table 2 lists the soil types that have been mapped in the project area. The soils in the project area formed by a variety of processes, resulting in complex soils with varying thicknesses. The general soil types based on the processes that formed them include:

- Alluvial soil (alluvium) that was deposited directly by streams and rivers. Alluvial soils are restricted to the valley bottoms in the project area.
- Glacial soil that was deposited directly by glaciers (glacial till) and by glacial outwash streams (glaciofluvial deposits). Glacial depositional processes and their consequent deposits are described more fully in Section 3.2, Geology.
- Residual soils (residuum) that formed by weathering in place of the underlying bedrock, alluvium, or glacial deposits. The composition of residual soil depends on the type of underlying geologic parent material and its weathering characteristics; i.e., whether the soil is predominantly fine-grained (silt and clay) or coarse-grained (sand and gravel). In general, residual soil is relatively thin in the project area.
- Colluvial soil (colluvium) has been transported downslope, generally by mass wasting (e.g., landsliding and soil creep). Colluvial soil may cover a layer of residual soil derived from the underlying parent material.
- Volcanic ash from nearby Cascade volcanoes periodically fell over the area and mixed with the other soil types.

The soil units shown on the Soil Map, Figure 5, and described in Table 2 generally can be grouped based on the underlying parent material. The Barneston, Edgewick, Humaquepts, Klaus, Nargar, Ragnar, Skykomish, Sulsavar, and Winston soils generally overlie glacial outwash. Beausite, Chuckanut, Elwell, Norma, Oakes, Rober, Tokul, and Welcome soils typically overlie glacial till. Soils that overlie bedrock units include Beausite, Chuckanut, Gallup, Harnit, Kaleetan, Kankaskat, Littlejohn, Ogarty, Ovall, Pitcher, Playco, Reichel, Stahl, and Welcome. Many of the soil units have some admixture of volcanic ash.

Most of the soils in the project area are more than 5 feet deep, reflecting the depth of underlying glacial and alluvial deposits. Thinner soil is present in areas underlain by bedrock, shown on the Geologic Map, Figure 3. The depth of soil in areas underlain by bedrock ranges from 0 to more than 5 feet, but typically is between 2 and 4 feet. Soils underlain by bedrock are typically thinner on steep slopes underlain by massive, erosion-resistant sandstone and volcanic flow rock. The soil depth can influence surface water runoff and mass wasting potential.

3.4 Regional Seismological Setting

The project site is located in a moderately active tectonic region that has been subjected to numerous earthquakes of low to moderate strength and occasional strong shocks during the brief 170-year historical record in the Pacific Northwest. The tectonics and seismicity of the region are the result of ongoing, oblique, relative northeastward subduction of the Juan de Fuca Plate beneath the North American Plate along the Cascadia Subduction Zone. The convergence of these two plates not only results in east-west compressive strain (Lisowski, 1993), but also results in dextral shear, clockwise rotation, and north-south compression of accreted crustal blocks that form the leading edge of the North American Plate (Wells and others, 1998). The subduction zone extends from Northern California to central Vancouver Island in British Columbia. Western Washington is located in the continental fore-arc of the Cascadia Subduction Zone. The fore-arc consists of accreted sedimentary and volcanic rocks (i.e., Olympic Mountains and Puget Lowland) in front of a landward mountainous, active volcanic arc (Cascade Mountains). The project site is located at the juncture between the accreted rocks and the landward mountainous, volcanic arc.

Within the present understanding of the regional tectonic framework and historical seismicity, three seismogenic sources have been identified (Yelin and others, 1994; Rogers and others, 1997). These include:

- A shallow crustal zone within the North American Plate.
- A deep subcrustal zone (intraslab) in the subducted Juan de Fuca Plate and Gorda plates.
- The Cascadia Subduction Zone, which is the interface between the North American and Juan de Fuca plates beneath the coast.

3.4.1 Shallow Crustal Earthquakes

Shallow crustal earthquakes within the North American Plate beneath the Puget Lowland have historically occurred in a diffuse pattern, typically within 12 miles of the earth's surface. The largest historic event is the 1872 North Cascades earthquake (estimated magnitude 7.0+ in the vicinity of Lake Chelan). However, surface rupture from this large event or other historic shallow crustal earthquakes in the Puget Lowland or Cascade Mountains have not been observed. Two faults with known or suspected Holocene movement (i.e., movement within the last 10,000 years) are the Seattle and South Whidbey Faults. The location of these faults relative to the site is shown on the Vicinity Map, Figure 1. The Seattle Fault is an approximately 1½- to 4-mile wide (north-south) zone consisting of multiple east-west trending strands (Johnson and others, 1999) that extends from near Hood Canal on the west to the Sammamish Plateau on the east. The east end of the southernmost strand (as mapped by Gower, 1985) is approximately 8 miles northwest of the north end of the project. As mapped by Rogers and others (1996), the South Whidbey Fault extends southeast from near Vancouver Island beneath the south end of Whidbey Island and terminates at the foot of the Cascades Mountains on the north side of Mount Si. The northwest-southeast trending South Whidbey Fault is located approximately 8 miles northeast of the project area.

Three northwest-southeast trending faults, the Rattlesnake Mountain, Raging River and Piling Creek Faults, are located within the project area, as shown on the Geologic Map, Figure 3. These faults were inferred based on offsets in Tertiary rock. However, no offset or displacement of overlying Vashon glacial deposits is indicated, which infers that no movement large enough to cause ground rupture has occurred on these faults since deposition of the Vashon deposits (i.e., no ground surface rupture within the last 13,500 to 15,000 years).

3.4.2 Intraslab Earthquakes

Deep subcrustal intraslab earthquakes can occur in the subducted portions of the Juan de Fuca Plate beneath the North American Plate, typically at depths of 25 to 38 miles. Earthquakes within this zone are associated with tensional forces that develop in the subducted plate due to mineralogical and density changes in the plates at depth. Large historic earthquakes from this source zone beneath western Washington include the magnitude (M_s) 7.1 Olympia earthquake of April 13, 1949 and the magnitude (m_b) 6.5 Seattle-Tacoma earthquake of April 29, 1965. Ludwin and others (1991) estimate that the maximum magnitude from this source zone would be about 7.5.

3.4.3 Cascadia Subduction Zone Earthquakes

The third seismogenic zone is near the line of subduction separating the Juan de Fuca Plate from the North American plate, west of the Pacific Northwest coast. The Cascadia Subduction Zone is presently generally quiet, with only scattered and diffuse seismicity. No large subduction earthquakes have occurred in this zone during historic times (170 years). However, geologic evidence suggests that coastal estuaries have experienced rapid subsidence at various times within the last 2,000 years (Atwater, 1987; Atwater, 1997). Atwater postulated that this subsidence resulted from movement along the Cascadia Subduction Zone. Earthquake magnitudes, rupture lengths, and recurrence rates have not yet been well defined for this zone. However, it appears that ruptures of this zone have occurred at irregular intervals that span from about 100 to more than 1,200 years with an average recurrence interval of about 500 years. The last large earthquake is estimated to have occurred about 300 years ago, based on the geologic evidence and historical Japanese tsunami records. Weaver and Shedlock (1997) estimate that rupture of this zone could result in earthquakes with magnitudes on the order of 8½ to 9.

3.4.4 Ground Motions

The USGS has conducted regional probabilistic ground motion studies to estimate potential earthquake ground motions considering the proximity and activity of the various earthquake source zones (Frankel and others, 1996). This study indicates that for ground motions with a 10 percent chance of being exceeded in 50 years (about a 500-year recurrence interval), random crustal earthquakes (i.e., earthquakes occurring on unknown or unidentified faults in the crust) are the greatest contributor to the ground motion hazard. While not as great, intraslab earthquakes also comprise a significant portion of the ground motion hazard. Peak ground accelerations (PGA) on bedrock consistent with a 10 percent chance of exceedance in 50 years are between 0.27g at the north end of the project area and 0.26g at the south end.

3.5 Hydrology

3.5.1 Precipitation

Precipitation patterns in the project area are under the prevailing marine influence of the Pacific Ocean, which produces mild, wet falls and winters, relatively dry summers, and mild temperatures year round. Most of the precipitation falls as rain in the southern lowlands of the project area, while a mixture of rain and snow falls on the upper portions of the northern mountainous area. Annual precipitation in the project area averages between 60 and 80 inches. In general, the annual precipitation amounts increase from west to east. There is a distinct wet season; over 75 percent of the total annual precipitation falls between October and April.

3.5.2 Flooding

The Federal Emergency Management Agency (FEMA) National Flood Insurance Program mapping program, usually conducted in populated areas, identifies areas that have a one percent chance of being flooded in any given year. These areas typically are referred to as the 100-year floodplain. Floodplain mapping by FEMA has not been accomplished in the project area. However, FEMA has mapped the 100-year floodplain along the Cedar River a short distance downstream from the project area. Based on this mapping, it appears that the 100-year floodplain is limited to a narrow area along the active Cedar River channel. The

Raging River, its tributaries, and tributaries to the Cedar River are in moderately incised channels. As such, these streams do not have significant floodplains and flooding generally would not overtop the incised channels. Therefore, towers and roads constructed above the stream channels should not affect or be affected by the stream flood characteristics.

3.5.3 Federal Clean Water Act

The Federal Clean Water Act requires that states protect the water quality of their rivers, streams, lakes, and estuaries. To accomplish this, Section 303(d) of the Clean Water Act requires that each state develop a list of water bodies that do not meet the standards. The 303(d) list is a means of identifying water quality problems. Once a stream is placed on the list, the Clean Water Act requires that the state develop a plan to reduce pollution. The states must submit the "water quality limited" list to the Environmental Protection Agency (EPA) every two years. In Washington State, the Department of Ecology (Ecology) is responsible for developing the standards that protect beneficial uses such as drinking water, cold water for fish, industrial water supply, and recreational and agricultural uses. Ecology is also responsible for compiling the 303(d) list and submitting it to EPA for approval. Parameters that Ecology typically monitors include bacteria, pH, dissolved oxygen, temperature, total dissolved gas, certain toxic and carcinogenic compounds, habitat and flow modification, fecal coliform, turbidity, and aquatic weeds or algae that affect aquatic life.

The proposed transmission line routes cross the following water bodies in the project area: Cedar River, Raging River, Rock Creek, Taylor Creek, Steele Creek, and Canyon Creek. At this time, none of these water bodies in the project area are listed on the Washington State 303(d) water quality limited water bodies list. Therefore, no water quality limiting factors are identified in the project areas that would be affected by construction, operation, and maintenance of the proposed new transmission line. The Cedar River is listed for fecal coliform west of the project area. In our opinion, the proposed action should not increase fecal coliform upstream from the listed portion of the Cedar River.

The project area includes portions of the City of Seattle Cedar River Watershed. Both water quality and quantity are important components of the Cedar River Watershed's ability to provide a clean and reliable drinking water supply. The existing water quality of the Cedar River is high. Degradation in water quality could affect the City of Seattle's ability to meet federal regulations for the treatment of surface water and potentially increase public health risks.

3.5.4 Groundwater

No sole-source aquifers designated or proposed by the US Environmental Protection Agency (EPA) exist in the project area; however, domestic wells are located within the project area. The principal groundwater aquifers are in glacial outwash deposits in the southern lowland area. These aquifers are locally developed for domestic and some farm consumption in the communities of Selleck and Kangley. In the northern mountainous area, the community of

Halmar Gates, near the end of Kerriston Road, likely uses groundwater for domestic consumption. Wells in this area would produce groundwater from the underlying bedrock.

3.6 Wind

Wind can affect the stability of transmission lines and towers. Wind can also affect forests adjacent to the cleared ROW. High winds can cause windthrow, which affects timber resources and poses a potential hazard to transmission lines.

During our helicopter overflight and field visits we observed an area of windthrow along a timber harvest buffer leave area along Canyon Creek. The area adjacent to the leave areas had been recently clearcut harvested. Canyon Creek is a tributary to the Raging River and is located about one mile south of the Echo Lake Substation along Alternative 3. The windthrow indicated that strong southerly winds occur through the Raging River Valley.

Chapter 4 Environmental Consequences

This chapter discusses the environmental consequences of the proposed alternatives on the resources described in the previous chapter. The chapter is divided into three general areas of resources: Geology and Soils, Seismic, and Hydrology and Climate. Each of these sections first defines impact levels for or each resource, generally using a scale with impact levels of high, moderate, low, and no impact. Next, is a discussion of general impacts that are common to all of the proposed alternatives and a general background regarding impacts to each resource. Following the general discussion of impacts, the impacts that could occur along each alternative are described in detail, together with a description of mitigation measures that likely would be required, cumulative impacts, and unavoidable effects, irreversible or irretrievable commitments of resources.

4.1 Geology and Soil

4.1.1 Geology and Soil Impact Levels

Direct impacts from the project would be caused by new access road construction, improvements to existing access roads, ROW clearing, and site preparation for construction of structures. During construction, these activities would disturb the soil surface, which could lead to an increase in soil erosion, runoff, and sedimentation in nearby water bodies. Long term maintenance, and especially ROW maintenance, could impair soil productivity and remove land from timber and farm production or other uses.

The following sections describe potential environmental consequences from construction, operation and maintenance of the proposed BPA Kangley-Echo Lake transmission project in hazard areas identified along each of the proposed alternative routes. Of the identified hazards, landslides and soil erosion resulting from construction, operation and maintenance of the project are most likely to have impacts on environmental resources (fish and water).

Landslide Impact Levels – Landslide impacts could occur if construction or maintenance of the proposed project triggers a landslide, or if a landslide is triggered by natural factors, such as a large storm, combined with factors related to the line.

Deep-seated landsliding has the greatest potential to impact a transmission alignment; however the potential for a deep-seated landslide is relatively small. Only one deep-seated landslide was identified along the alternative routes on the south flank of Brew Hill along Alternative 1 (Sheet 2 of Figure 5). This landslide feature is apparently ancient and does not appear to be active. Portions of the alternative routes were assigned a high, moderate, low, or no deep-seated landslide hazard category as follows:

- High deep-seated landslide hazard was assigned to areas with active deep-seated landsliding, or where numerous ancient deep-seated landslides were identified adjacent to the alignment. No high, deep-seated landslide hazard areas were identified in the project area.

- Moderate deep-seated landslide hazard was assigned to areas where isolated ancient deep-seated landslides were identified near the alignment. The ancient landslide on the south flank of Brew Hill is the only moderate deep-seated landslide hazard in the project area.

- Low deep-seated landslide hazard was assigned to areas that had similar characteristics as the moderate hazard landslide areas (i.e., slope, dip of bedded rocks, geologic contacts, etc.), but no landslides were identified nearby.

- No deep-seated landslide hazard was assigned to areas where deep-seated landslides were not identified and the geologic conditions do not appear conducive to deep-seated landsliding. Most of the project area falls within this category.

No shallow landslides were identified along the alignment, either on the aerial photographs or during the field reconnaissance. Shallow landslide hazards were assigned to a high, moderate, low or no shallow landslide hazard category as follows:

- High shallow landslide hazard was assigned to those sections of the alternative routes on slopes that exceed 65 percent and that are in the vicinity of mapped or observed areas of concentrated past shallow landslide movement. No high shallow landslide hazard areas were identified in the project area.

- Moderate shallow landslide hazard was assigned to those sections of the alternative routes on slopes that exceed 65 percent and are in the vicinity of isolated shallow landslides. No moderate shallow landslide hazard areas were identified in the project area.

- Low shallow landslide hazard was assigned to those sections of the alternative routes where no existing shallow landslides were identified, but where converging slopes exceed 65 percent or where slopes steeper that 40 percent are present in confined drainages.

- No shallow landslide hazard was assigned to all remaining sections of the alternative routes not identified as high, moderate, or low.

Soil Erosion Impact Levels – Potential soil-related impacts in the project area were evaluated and mapped using the Soil Survey of Snoqualmie Pass Area, Parts of King and Pierce Counties, Washington (USDA, 1992). The soil survey includes soil maps and descriptions of soil composition and structure. They also describe the soil engineering characteristics, such as Unified Soil Classification (USC), grain size, plasticity, erosion potential and organic content.

Surface erosion of soil can occur as a result of wind and downslope movement, such as creep or ravel; however, soil erosion is most often associated with flowing water. Soils that are most susceptible to surface erosion by water have no or minor cohesion (as a result of a low percentage of clay minerals) or have a low percentage of gravel-size particles (which would otherwise armor the soil surface). Other factors that lead to high rates of soil erosion are disturbance, absence of vegetative cover, concentrated water and steep slopes.

Table 7 of the Soil Survey of Snoqualmie Pass Area (USDA, 1992) defines soil erosion hazards of slight, moderate and severe, which indicate the risk of loss of soil in *well-managed woodland* (italics added for emphasis). These ratings are summarized below. Table 2 of this report lists these soil hazard ratings, as defined by the USDA (1992) for the soils that occur in the project area.

- <u>High erosion impact</u> was assigned to those sections of the routes that cross soil units identified as severe erosion hazards. These soils may require intensive management or special equipment and methods to prevent excessive loss of soil. The Tokul gravelly loam on slopes steeper than 45 percent is the only soil with a severe erosion hazard that would be crossed by the proposed Alternative routes (Alternatives 1 and 3).

- <u>Moderate erosion impact</u> was assigned to those sections of the alternative routes that cross soil units identified as moderate erosion hazards. These soils may require erosion control measures during logging and road construction to prevent excessive loss of soil.

- <u>Low erosion impact</u> was assigned to those sections of the alternative routes that cross soils identified as slight erosion hazards. Loss from these soils during construction is expected to be small.

- <u>No erosion impact</u> would occur only in soils that are not disturbed during the construction and maintenance of the proposed project.

Excavation Difficulty Impact Levels – The degree of excavation difficulty for road and transmission line tower construction is based on expected depths of soil and bedrock, and the expected strengths of bedrock. An average excavation depth of 15 feet was assumed for tower footings. Similar excavation depths can be assumed for road construction (i.e., cut slopes). For assigning excavation difficulty, rock is defined as material that requires blasting or use of hydraulic breakers for excavation. Material that can be excavated entirely with conventional earth-moving equipment, including rippers, is considered to be soil.

Although excavation difficulty does not represent a hazard to the environment, the type of excavation required does affect the construction methods used, which in turn can affect the environment. Excavation difficulty ratings of high, moderate, and low were assigned based on the expected geologic unit and the following criteria:

- <u>High excavation difficulty</u> was assigned to areas that are underlain by bedrock, which includes the sedimentary Tukwila, Raging River, and Tiger Mountain Formations, and intrusive, volcanic and volcanicalstic rocks. Much of the near-surface rock can probably be ripped and/or excavated by machine. However, deeper excavations or excavations in harder or more massive bedrock may require blasting and/or hydraulic breaking.

- Moderate excavation difficulty was assigned to areas that are underlain by glacial till and other glacially-overridden soils (advance outwash and some ice-contact deposits). In general, these soil types can be excavated with conventional excavation equipment. However, excavation may require large earthwork equipment and rates may be slow. Local boulder deposits and unanticipated bedrock outcrops may require hydraulic breaking and/or blasting to complete excavations.

- Low excavation difficulty was assigned to the remaining sections of the alternative routes that were not assigned a moderate or high hazard. While the potential for rock excavation is small, there is the possibility of encountering large boulders, rockslide blocks, or other unidentified, hard or massive rock.

Settlement Impact Levels – Settlement occurs when soft or loose soil consolidates or densifies under loads. Loads can include fill placed for a road or foundations of a transmission line tower or other structure. Wet, fine-grained soil or soil that contains abundant organic material usually have the greatest potential for settlement. These types of soil typically occur in alluvial environments, such as river valleys, bays, and estuaries. Poorly compacted fills and fills with organic material are also susceptible to settlement.

Settlement impact levels were assigned as follows:

- High settlement impact was assigned to areas where structures might be built on swampy areas and recent alluvium.

- No settlement impact was assigned to all other areas.

4.1.2 Geology and Soil General Impacts

Landslides – Poor practices in design and construction of access roads and clearing of wide swaths of forest on slopes that are susceptible to landsliding may cause an increase in the rate and/or size of landslides. The factors that affect landsliding, other than natural factors, include poor road construction practices, improperly placed fills, poorly-designed cut slopes, poor drainage, and, to a lesser degree, logging. Fills placed for roads on slopes steeper than about 60 percent, poorly compacted fills, poor quality fill material, and poorly prepared subgrades create conditions that are particularly susceptible to landsliding. A steep cut that is made in poorly drained soil or in loose, granular soil could initiate a landslide. Landslides are commonly triggered by poor road drainage resulting from undersized culverts, culverts that are spaced too far apart, blocked culverts, or from poorly maintained roads and ditches. Logging dense coniferous forests on steep slopes could increase the potential for landslides to occur as a result of reduced soil strength. Reduced soil strengths can occur from increased soil water that results from the loss of interception and evapotranspiration of precipitation, and to a lesser extent, the loss of root strength.

Most shallow landslides would probably not significantly impact the transmission line towers. However, they could increase the rate at which sediment and debris is delivered to streams, reduce the amount of land for timber production, and cause temporary access road closures.

Shallow landslides can liquefy after moving a short distance and become debris flows. Debris flows typically move rapidly down the slope, eroding and accumulating additional material until they reach a low gradient slope or the valley bottom.

Deep-seated landslides could deposit large quantities of debris into streams, which, in turn, may degrade fish habitat and water quality. Because of their potential size, deep-seated landslides can have a significant impact on existing public and private roads and properties that are downslope of the landslide. Movement of a deep-seated landslide across the transmission line ROW could displace or topple the towers and potentially snap or short the conductors. Small, chronic movements of the landslide mass would require frequent maintenance. Deep-seated landslides can be initiated by poorly-designed road cuts, excessive fills, or discharge of excessive concentrated drainage. Inactive, deep-seated landslides can be reactivated by excavating cuts at the toes, placing fills at the tops, or by discharging excessive concentrated water onto the slide body.

Soil Erosion – Construction of roads, ROW clearing, and site preparation for transmission line tower footings and the substation facilities will expose and disturb soil, increasing the potential for surface erosion of soil from its pre-disturbed condition. The eroded soil could enter streams and impact fish habitat and water quality. Sources for increased sediment include unprotected cut and fill slopes, road surfaces, and spoil piles. Most impacts would likely be short term. Once the cuts and fills adjacent to roads and the areas cleared for tower construction revegetate, the road surfaces are graveled or naturally become armored, and the substation construction is complete, erosion rates should reduce substantially and not significantly affect nearby streams and other water bodies. Long-term impacts should be small unless efforts to revegetate and control erosion and runoff are unsuccessful and/or not maintained.

Excavation Difficulty – Based on expected soil depths and rock strengths, excavation for most of the roads and footings can be accomplished with conventional earthwork equipment. However, some sections of the access roads may require blasting to remove massive and/or hard bedrock, while some tower foundations may require drilled rock anchors. Blasting of the bedrock could temporarily disturb residents living nearby and wildlife. Excavations in soil can generate spoils and create slopes that typically are more susceptible to erosion than bedrock spoils and slopes.

Settlement Hazard – Transmission line towers founded improperly on soil that is settlement-prone could settle differentially to the point that they would not function as designed. Settlement induced by constructing the transmission line towers could have indirect environmental impacts as a result of additional maintenance work and possible construction of new foundations.

4.1.3 Alternative 1 Geology and Soils

4.1.3.1 Alternative 1 Impacts

Alternative 1 parallels the existing Raver-Echo Lake transmission line, so that most of the road system is already in place. As a result, in most cases, only short spur roads to the actual tower sites from the existing roads would be needed. Small intermittent streams may be crossed by these spur roads and culverts could be required for passage of storm water.

Landslides – One area of moderate deep-seated landslide hazard was identified along an approximate 3,000-foot long portion of Alternative 1 (Table 3). This area is the ancient deep-seated landslide that has been mapped in Section 35 on the southeast flank of Brew Hill and across which the existing transmission line traverses (Figures 3 and 5). However, observations made during the field evaluation did not indicate unstable slopes or recent movement in this mapped landslide area. No high or low deep-seated landslide hazard areas were identified along Alternative 1.

High or moderate shallow landslide hazard areas were not identified along Alternative 1. Low shallow landslide hazard areas (Table 3 and Figure 5), totaling about 2,500 feet in length, were identified at:

- The north and south slopes above the Cedar River in Section 14.
- The stream crossings on the north and south sides of Brew Hill, Sections 26 and 35, respectively.
- The north and south slopes above the Raging River, Section 14.

Road construction across the mapped deep-seated landslide feature could reactivate a portion of this landslide. Poor design and road construction practices, excessive road drainage or poor maintenance of roads in the areas of shallow landslide hazard could initiate a landslide that could deliver sediment to fish-bearing waters. Because a road system already exists along most of Alternative 1 and only short spur roads should be required, the potential for project-related, road-initiated landslides should be small.

Existing design standards for the proposed transmission line alignment call for a clearing width of 150 feet. This would require the clearing of approximately 165 acres of second- and third-growth timberland (Table 3). Because Alternative 1 parallels an existing cleared alignment, the clearing width could potentially be reduced. Additional clearing would also be required for access road construction. However, because extensive new road would not be required for this alternative, the amount of clearing for roads will be relatively small. Landslides could be triggered in the areas identified as shallow landslide hazard due to hydrologic change as a result of cleared transmission line corridors. However, evidence of past shallow landsliding was not observed along the existing transmission line corridor in the areas of shallow landslide hazard.

Soil Erosion – The total length of the Alternative 1 route is approximately 9 miles. Of this, about 0.3 miles (3%) cross soil designated as a severe erosion hazard, 1.4 miles (15%) cross soil designated as a moderate erosion hazard, and the remaining 82% of the route crosses soil designated as a slight erosion hazard (Table 3 and Figure 5). The severe erosion hazard occurs on the slopes above the Raging River.

Poor design and construction or poor maintenance activities on the severe and moderate hazard soil erosion areas could increase soil erosion and delivery of sediment to fish-bearing waters. In most cases, only short spur roads from the existing roads to the actual tower sites would be needed. In addition, the need for construction of additional culverts and bridges, and the resulting potential impacts to water bodies, would be significantly reduced compared to the number of similar drainage structures required for a new road system. Culverts may be required where the short spur roads cross small, intermittent streams.

The increased amount of surface water runoff resulting from the lengthened road prism and additional cleared slopes could potentially cause an increase in peak flows. Increased surface runoff and peak flows can cause additional erosion at road cuts and fills, along drainage ditches, below culvert outfalls, and in stream channels. However, the anticipated increase is expected to be small relative to existing conditions.

Excavation Difficulty – We did not observe rock outcrop along the Alternative 1 alignment, and soil units that are indicative of shallow bedrock were not mapped along Alternative 1 (Figure 5). Therefore, we do not anticipate that shallow, hard bedrock will be present that could cause difficult excavation conditions.

Boulder and gravel recessional outwash deposits are present south of the Cedar River along the alternative route. In addition, isolated glacial erratic boulders could be present in glacial till deposits; i.e., at almost all locations along the proposed alignment. Large boulders might require blasting to excavate for tower foundations, because, in most cases, rock anchors placed in large boulders would not form a suitable foundation.

Typically, tower foundations are placed to the same depth, whether in soft rock or soil, to provide sufficient resistance to uplift. Therefore, the amount of spoils generated should be similar for soft rock or soil excavation. However, the amount of material produced that is erodible by surface processes should be less for rock excavation than for soil excavation. Unless adequate mitigation measures are implemented, erosion of the spoils could deliver sediment to nearby water bodies.

Hard rock excavation could require the use of blasting and/or hydraulic breakers. These methods would generate more noise and dust than using excavation equipment only.

Settlement Hazard - No settlement hazards were identified along Alternate 1.

4.1.3.2 Mitigation

Where possible, hazard avoidance is the most effective method to mitigate impacts from or to the project facilities. During preliminary and final route selection (including tower and road locations), avoidance would be the primary means of mitigation. For those areas where potential natural hazards are present and unavoidable, measures to mitigate impacts that could result from the construction, operation and maintenance of the project can be implemented. Site-specific mitigation measures would be developed following selection of a specific route.

Roads - Most landslide and soil erosion impacts probably would be the result of road construction and use. Therefore, the most direct way to reduce these impacts is to reduce the amount of new road construction. Access roads would be required to clear the alignment ROW and to construct and maintain each transmission line tower. Typical transmission line tower spacing will be about 1,100 to 1,200 feet, except where longer spans are required to cross streams such as the Raging River and the Cedar River. Modern logging techniques utilizing cable systems also allow more ground to be accessed with fewer roads.

Once a specific route is selected, the proposed access road alignments should be evaluated in the field to identify site-specific hazards. Engineering analyses should be conducted and road stabilization measures designed and constructed where required. An Erosion and Sediment Control Plan (ESCP) that incorporates Best Management Practices, (BMPs) would be developed and implemented for specific areas, such as road crossings at streams, to minimize delivery of sediment to sensitive resources. To reduce the potential for road failures, roads could be located along ridge tops wherever feasible. Roads along or near ridge tops are more stable because deep side cuts across slopes and side hill fills generally are not required, and stormwater runoff is typically less intense. Seasonal restrictions can be placed on road construction operations to reduce the potential of erosive events and impacts to wildlife.

Erosion of fine sediment from road surfaces can contribute sediment to a drainage system. To reduce surface erosion, those roads that will be actively used could be surfaced with sound crushed rock and maintained on a regular basis. Maintenance can include grading, ditch and culvert cleaning, cut slope revegetation, and repair of identified potential failure sites. Roads that will not be used following construction should be restored to approximately pre-existing conditions or stabilized with vegetation and drainage measures (e.g., water bars, removing culverts, and sidecast fill removal).

Right-of-Way Clearing - Under local regulations, wetlands and streams are required to have protective buffers. Wetlands, streams, and associated buffers would be left undisturbed where practical.

Disturbance of the soil cover during logging should be low if using cable or appropriate ground-based logging methods. A low ground cover of vegetation consisting of shrubs and grasses would remain following logging and the cleared area would not be burned. Over the years, this vegetation will grow to a taller, denser condition. Consequently, the benefits of vegetation, including root strength, soil cover, interception and evapotranspiration of precipitation, will remain.

Other Mitigation Measures -

- Properly space and size culverts; use crossdrains, water bars, rolling dips, and armoring of ditches, and drain inlets and outlets.

- Improve all existing culverts and stream crossings that pose a risk to riparian, wetland, or aquatic habitat to accommodate at least a 50-year flood and associated bedload and debris.

- Coordinate all culvert installations with the appropriate federal, state and local agencies.

- Preserve existing vegetation where possible and stabilize disturbed portions of the site. Implement stabilization measures as soon as practicable where construction activities have temporarily or permanently ceased.

- Promptly seed disturbed sites with an approved herbaceous seed mixture suited to the site.

- Use vegetative buffers and sediment barriers to prevent sediment from moving off-site and into water bodies.

- Design and construct fords and bridges to minimize bank erosion. Identify specific locations and measures when road and line designs are finalized.

- Schedule construction and maintenance operations during periods when precipitation and runoff potential is at a minimum to reduce the risk of erosion, sedimentation, and soil compaction.

- Design facilities to meet regional seismic criteria.

- Use full-bench road construction and end hauling of excess material on slopes exceeding 60 percent, if needed to stabilize road prisms. Prior to construction, locate suitable waste areas for depositing and stabilizing excess material.

- Construct access roads consistent with the standards and guidelines of the Washington State Department of Natural Resources and other applicable guidelines.

- Avoid riparian areas, drainage ways, and other water bodies. Where these areas cannot be avoided, apply sediment reduction practices to prevent degradation of riparian or stream quality. Consider using riparian plantings where needed to restore streamside vegetation and insure streambank stability.

- Restrict road construction to the minimum needed and obliterate non-essential existing roads and temporary construction access roads.

- Avoid discharge of solid materials, including building materials, into waters of the United States unless authorized by a Section 404 permit of the Clean Water Act. Reduce off-site tracking of sediment and the generation of dust. Leave vegetative buffers along stream courses to minimize erosion and bank instability.

- Prepare a Stormwater Pollution Prevention Plan (SWPPP), as required under the National Pollution Discharge Elimination System General Permit.

- Design the project to comply with local regulations and state and federal water quality programs to prevent degradation of aquifer quality and avoid jeopardizing their usability as a drinking water source.

4.1.3.3 Cumulative Impacts

Current and future forest management practices in the watersheds that Alternative 1 crosses might increase peak flows and introduce sediment into streams. Increased sediment and peak flows in streams is expected from construction and operation of the line alternatives in addition to forest management activities. The volume of peak flow and the amount of sediment entering streams would depend on site-specific conditions. Mitigation measures proposed for construction of the line and those required for logging-related activities would reduce the chance of large amounts of sediment entering streams. Although minor, localized increases in erosion, runoff, and sedimentation are expected from construction and maintenance, these increases would have a low impact on the area's soil resources and water quality, and should not impair the current beneficial use of water bodies.

4.1.3.4 Unavoidable Effects, Irreversible or Irretrievable Commitments of Resources

Additional land clearing and road construction, with their attendant short- and long-term impacts discussed above, are unavoidable in order to complete the proposed project. If the project is abandoned, the disturbed ground could be restored and, over a period of years, revegetated to pre-existing conditions. Resources, such as fuel oil, lubricants and metals, will be consumed during construction and maintenance of the project. Aggregate materials will be used in road and tower foundation construction, and for road surfacing maintenance. These materials will require mining and transportation.

4.1.4 Alternative 2 Geology and Soils

4.1.4.1 Alternative 2 Impacts

The Alternative 2 alignment differs from the Alternative 1 alignment along the last segment at the south end where it crosses the Cedar River. From the tap point of the Schultz-Raver No. 2 line north to Anacortes Road (Cedar River Watershed road No. 80), the route crosses a relatively recent clearcut. From Anacortes Road north to the Cedar River, tower locations likely would be within 200 to 300 feet of Pole Line Road (Cedar River Watershed Road No. 50), Road No. 54 or the Railroad ROW (Cedar River Watershed Road No. 9). North of the Cedar River, Rocky Road (Cedar River Watershed Road No. 40), Road No. 10.4a, Green Valley Road (Cedar River Watershed Road No. 31) and Road No. 32 provide access to within about 500 feet of most likely tower locations. One tower location may be about 800 to 1,000 feet from an existing road. These spur roads may cross small intermittent streams that could require culverts.

Landslides – No shallow or deep-seated landslide hazard areas were identified along the Alternative 2 alignment, except where Alternative 2 coincides with Alternative 1 (see Section 4.1.3.1). Low shallow landslide hazard areas are slightly less widespread than Alternative 1 (3% of alignment length instead of 5% for Alternative 1) because of the alternate crossing of the Cedar River (Table 3 and Figure 5).

Numerous roads exist along Alternative 2 and along the portion of Alternative 1 that coincides with Alternative 2. As a result, only relatively minor road building would be required, generally consisting of short spur roads. The Alternative 2 segment across the Cedar River valley typically crosses gentle to moderately sloped ground, such that new roads, where required, should not require large cuts or fills.

Alternative 2 is also approximately 9 miles long. Assuming a 150-foot wide transmission line corridor, approximately 165 acres of second and third-growth timberland would need to be cleared (Table 3).

Impacts to slope stability from Alternative 2 land clearing and road construction will be similar to those of Alternative 1 (see Section 4.1.3.1)

Soil Erosion – About 0.3 miles (3%) of Alternative 2 cross soil designated as a severe erosion hazard, 1.4 miles (15%) cross soil designated as a moderate erosion hazard, and the remaining 82% crosses soil designated as a slight erosion hazard (Table 3 and Figure 5). The severe erosion hazard occurs on the slopes above the Raging River.

Because of the lack of streams across the route, the moderate- to low-sloped ground, and the number of existing roads adjacent to Alternative 2, new tower construction access roads will generally not require stream crossings with their attendant potential erosion and sedimentation impacts. Culverts may be required where the short spur roads cross smaller, intermittent streams.

Impacts of project construction and operation on soil erosion and sediment delivery will be similar to those impacts described for Alternative 1 (see Section 4.1.3.1).

Excavation Difficulty – We did not observe rock outcrop along the Alternative 2 alignment. Soil units that are indicative of shallow bedrock were not mapped along Alternative 1 (Figure 5). Excavation difficulty, and its associated impacts, should be similar to Alternative 1 (see Section 4.1.3.1).

Settlement Hazard - No settlement hazards were identified along Alternate 2.

4.1.4.2 Mitigation

Refer to measures under Alternative 1, see Section 4.1.3.2.

4.1.4.3 Cumulative Impacts

Refer to measures under Alternative 1, see Section 4.1.3.3.

4.1.4.4 Unavoidable Effects, Irreversible or Irretrievable Commitments of Resources

Refer to effects and commitments under Alternative 1, see Section 4.1.3.4).

4.1.5 Alternative 3 Geology and Soils

4.1.5.1 Alternative 3 Impacts

From the tap point of the Schultz-Raver No. 2 line north to Anacortes Road, Alternative 3 crosses the same clearcut as described for Alternative 2. From Anacortes Road north to Pole Line Road (Cedar River Watershed Road No. 50), the route and likely tower locations are within about 300 feet of Bonus Creek Road (Cedar River Watershed Road No. 53). The route would closely follow Pole Line Road along a gentle terrace northwest for 2 miles where it then would turn northeast and cross the Cedar River. New roads to this point would be limited to short spur roads from existing roads to each tower location and should not require large cuts of fills.

From the Cedar River, the route climbs about 900 feet over a horizontal distance of about 2,500 feet to a ridge, and then crosses Steele Creek. The tower locations on the slope would be adjacent to the Cedar Falls Road (Cedar River Watershed road No. 10), Road 20 and Road 21. Spur roads would be required for the towers on the ridge above and west of Steele Creek. These roads might be several thousand feet long, depending on the actual tower locations. Road cut and fills similar to those required for road No. 21 could be required where the spur roads cross slopes of 40 percent or steeper.

North of the Cedar River Watershed, Alternative 3 crosses gentle to moderate slopes over private timberland. The area has an existing, relatively dense road network used for logging activities. South of the Raging River (in the southwest ¼ of Section 30) most of the proposed route is within about 1,000 to 2,000 feet of existing roads. North of the Raging River, the proposed Alternative 3 route is within about 1,000 feet of existing roads.

Because of the existing road network, additional culverts and bridges should not be needed across the larger streams. However, a crossing will probably be required across a relatively large stream in Section 31 to access the alignment south of the Raging River.

Landslides – An area of low deep-seated landslide hazard north of the Cedar River and on the east bank of Steele Creek (Figure 5) was designated because conditions are similar to the mapped moderate landslide hazard area (i.e., similar bedrock with an adverse dip into the Cedar River Valley). No high or moderate hazard deep-seated landslide areas were identified along Alternative 3.

No high or moderate shallow landslide hazard areas were identified along Alternative 3. Low hazard shallow landslide hazard areas (Table 3 and Figure 5), totaling about 2,800 feet in length, were identified along the Alternative 3 alignment at:

- The stream crossings of Canyon Creek and the adjacent creek to the south, Section 13.

- The north and south slopes above the Raging River, Section 30.
- The east slopes above Steele Creek, Section 6.
- The east and west slopes above Taylor Creek, Section 13.

Alternative 3 is approximately 10.4 miles long. Assuming a 150-foot wide transmission line corridor, approximately 190 acres of second and third-growth timberland would need to be cleared (Table 3).

The type of impacts to slope stability from Alternative 3 land clearing and road construction will be similar to those of Alternative 1 (see Section 4.1.3.1). The greatest potential landslide impacts would occur on the steep slopes above the larger drainages listed as shallow landslide impacts above. A shallow landslide on one of these slopes could deliver sediment directly to a fish-bearing water body.

Soil Erosion – About 0.2 miles (2%) of Alternative 3 cross soil designated as a severe erosion hazard, 2.1 miles (20%) cross soil designated as a moderate erosion hazard, and the remaining 78% of the route crosses soil designated as a slight erosion hazard (Table 3 and Figure 5). The severe erosion hazard occurs on the slopes above the Raging River and Canyon Creek.

Although impacts from project construction and operation on soil erosion and sediment delivery would be similar to those impacts described for Alternative 1 (see Section 4.1.3.1), the relative amount of potential impacts will be greater because Alternative 3 will require more of new access road. More stream crossings with their attendant potential erosion and sedimentation impacts would be required with this alternative.

Excavation Difficulty – Some rock outcroppings are present along the Alternative 3 alignment. These outcrops are located on the slope north of the Cedar River and east of Steele Creek, and along the east flank of Rattlesnake Mountain between the northern Cedar River Watershed boundary and Canyon Creek. Much of the east flank of Rattlesnake Mountain is covered with a thin mantle of glacial till that obscures the underlying bedrock (refer to the Geologic Map, Figure 3). Typically, these rock outcrops are deeply weathered and can be excavated with conventional equipment to depths of 5 to 10 feet. Deeper excavations might require blasting or the use of a hydraulic impact hammer.

Soil units along Alternative 3 that typically form a relatively thin cover over hard bedrock include the following:

- Pitcher sandy loam (soil unit , which develops over andesite, is located on the slope north of the Cedar River, described above. The underlying rock is undifferentiated Puget Group volcanics.
- Ogarty gravelly loam, which commonly overlies andesite and volcanic breccia, is present west of the proposed alignment about 2 miles southeast of the Echo Lake Substation. Several borrow pits were made in the Tukwila Formation bedrock, which commonly

underlies the Ogarty gravelly loam, to a depth of 20 feet or more. It appeared that the excavations were made without blasting.

Settlement Hazard – An area of alluvium is mapped in the southeast corner of Section 13 on a terrace near the mouth of Taylor Creek. This area has been identified as a potential settlement hazard. No other settlement hazards were identified along Alternative 3. General settlement impacts are discussed in Section 4.1.2. Impacts to the environment resulting from settlement would include potential ground disturbance during repair and maintenance operations.

4.1.5.2 Mitigation

In general mitigation required for this alternative will be similar to Alternative 1 (see Section 4.1.3.2). However, because the length of this alternative is greater than the other alternatives, the mitigation measures may be greater. The potential excavation of hard rock might require some blasting. The timing of blasting may need to be coordinated to avoid conflicts with residents and wildlife. Subsurface explorations should be conducted to evaluate subsurface materials and their susceptibility for settlement under the expected loads. Foundation engineering measures, such as piles or overexcavation, could be employed to reduce the amount of settlement.

4.1.5.3 Cumulative Impacts

Refer to measures under Alternative 1, see Section 4.1.3.3.

4.1.5.4 Unavoidable Effects, Irreversible or Irretrievable Commitments of Resources

Refer to effects and commitments under Alternative 1, see Section 4.1.3.4).

4.1.6 Alternative 4A Geology and Soils

4.1.6.1 Alternative 4A Impacts

From the point Alternative 4A diverges from the Alternative 2 alignment to the southern Cedar River Watershed boundary, the likely tower locations would be within 300 feet of Anacortes Road. Depending on the actual tower locations, Road 80.2 could be used to provide access to one tower. North of the Cedar River Watershed boundary, one tower location would be close to Pole Line Road, and a second would be within 300 feet of Road No. 54. Therefore, new roads would be limited to short spur roads from existing roads to each tower location and should not require large cuts or fills. Other than culverts that may be needed along the portion of Alternative 1 that coincides with Alternative 4A, no additional bridges or culverts to cross streams should be required along this alternative.

Landslides – No shallow or deep-seated landslide hazard areas were identified along the Alternative 4A alignment, except where this alternative coincides with Alternative 1 (see Section 4.1.3.1). The landslide hazards along Alternative 4A are similar to those along Alternative 1 (Table 3 and Figure 5).

Relatively minor road building should be required because the trunk road system is mostly in place. New road would consist primarily of short spur roads. Alternative 4A is approximately 10 miles long. Assuming a 150-foot wide transmission line corridor, approximately 175 acres of second and third-growth timberland would need to be cleared (Table 3). Impacts to slope stability from Alternative 4A land clearing and road construction should be similar to those of Alternative 1 (see Section 4.1.3.1)

Soil Erosion – About 0.3 miles (3%) of Alternative 4A cross soil designated as a severe erosion hazard, 1.5 miles (15%) cross soil designated as a moderate erosion hazard, and the remaining 82% of the route crosses soil designated as a slight erosion hazard (Table 3 and Figure 5). Severe erosion hazard is present on the slopes above the Raging River.

Because of the number of existing roads adjacent to Alternative 4A, new access roads will generally not require additional stream crossings with their attendant potential erosion and sedimentation impacts. Culverts may be required where the short spur roads cross smaller, intermittent streams. Impacts of project construction and operation on soil erosion and sediment delivery will be similar to those impacts described for Alternative 1 (see Section 4.1.3.1).

Excavation Difficulty – We did not observe rock outcrop along the Alternative 4A alignment, and soil units that are indicative of shallow bedrock are not mapped along Alternative 4A (Figure 5). Therefore, we anticipate that excavation difficulty, and its associated impacts, will be similar to Alternative 1 (see Section 4.1.3.1).

Settlement Hazard - No settlement hazards were identified along Alternative 4A.

4.1.6.2 Mitigation

Refer to measures under Alternative 1, see Section 4.1.3.2.

4.1.6.3 Cumulative Impacts

Refer to measures under Alternative 1, see Section 4.1.3.3.

4.1.6.4 Unavoidable Effects, Irreversible or Irretrievable Commitments of Resources

Refer to effects and commitments under Alternative 1, see Section 4.1.3.4).

4.1.7 Alternative 4B Geology and Soils

4.1.7.1 Alternative 4B Geology and Soils Impacts

The segment of this route that connects portions of Alternative 2 to Alternative 1 follows Pole Line Road. Tower locations would be within 100 feet or less of the road. New roads would be limited to short spur roads from Pole Line Road to each tower location and should not require large cuts or fills.

Other than the additional culverts that may be needed along the portion of Alternative 1 that coincides with Alternative 4B, no additional bridges or culverts would be required along this alternative.

Landslides – No shallow or deep-seated landslide hazard areas were identified along the Alternative 4B alignment, except where this alternative coincides with Alternative 1 (see Section 4.1.3.1). The landslide hazards along Alternative 4B are similar to those along Alternative 1 (Table 3 and Figure 5).

Relatively minor road building should be required because the trunk road system is mostly in place. New road would consist primarily of short spur roads. Alternative 4B is approximately 10 miles long. Assuming a 150-foot wide transmission line corridor, approximately 185 acres of second and third-growth timberland would need to be cleared (Table 3). Impacts to slope stability from Alternative 4B land clearing and road construction should be similar to those of Alternative 1 (see Section 4.1.3.1)

Soil Erosion – About 0.3 miles (3%) of Alternative 4B cross soil designated as a severe erosion hazard, 1.5 miles (15%) cross soil designated as a moderate erosion hazard, and the remaining 82% of the route crosses soil designated as a slight erosion hazard (Table 3 and Figure 5). Severe erosion hazard occurs on the slopes above the Raging River.

Because of the number of existing roads adjacent to Alternative 4B, new tower construction access roads would generally not require additional stream crossings with their attendant potential erosion and sedimentation impacts. Culverts may be required where the short spur roads cross smaller, intermittent streams. Impacts of project construction and operation on soil erosion and sediment delivery will be similar to those impacts described for Alternative 1 (see Section 4.1.3.1).

Excavation Difficulty – We did not observe rock outcrop along the Alternative 4B alignment, and soil units that are indicative of shallow bedrock are not mapped along Alternative 4B (Figure 5). We anticipate that excavation difficulty, and its associated impacts, will be similar to Alternative 1 (see Section 4.1.3.1).

Settlement Hazard - No settlement hazards were identified along Alternative 4B.

4.1.7.2 Mitigation

Refer to measures under Alternative 1, see Section 4.1.3.2.

4.1.7.3 Cumulative Impacts

Refer to measures under Alternative 1, see Section 4.1.3.3.

4.1.7.4 Unavoidable Effects, Irreversible or Irretrievable Commitments of Resources

Refer to effects and commitments under Alternative 1, see Section 4.1.3.4).

4.2 Seismic

4.2.1 Seismic Impact Levels

Liquefaction Impact Levels – Liquefaction is a phenomenon in which saturated, cohesionless soils are temporarily transformed into a near liquid or "quick-sand" state. During an earthquake, ground shaking may result in a buildup of pore water pressure in the saturated soil to a point where the pore water pressure approaches the grain-to-grain contact pressure. As this occurs, the soil particles begin to loose contact with each other and the soil liquefies. The effects of liquefaction include lateral spreading (permanent lateral ground displacements up to about 10 feet on near-level ground), differential settlement, loss of vertical and lateral foundation support, and buoyant rise of buried structures. Historically, soils that have high liquefaction susceptibility include artificial fill (particularly along or in bodies of water) and granular Holocene geologic deposits (e.g., alluvium) in valley bottoms and along rivers and creeks.

Regional liquefaction studies (Grant and others, 1992; Palmer, 1992; Palmer and others 1994, 1995a, 1995b) indicate that late Pleistocene, non-glacially overridden deposits have a moderate to low liquefaction susceptibility, while Pleistocene and older, glacially-overridden sediment and rock have a low liquefaction susceptibility. The Geologic Map, Figure 3, shows the locations of these deposits along the alternative alignments. Liquefaction impact levels were assigned to these units as follows:

- <u>High liquefaction impact</u> was assigned to Holocene alluvium along the Cedar River.
- <u>Moderate to low liquefaction impact</u> was assigned to Pleistocene, recessional glacial outwash near the Cedar River.
- <u>No liquefaction hazard</u> was assigned to all other deposits.

Soft Ground Amplification Impact Levels – Earthquake ground motion or waves can resonate in relatively soft, cohesive soil resulting in local ground motion amplification. The amount of ground motion amplification depends on the characteristics of the earthquake and the thickness and properties of the soil. Soft, cohesive soil (e.g., clay, peat, and organic soils) are typically geologically-recent alluvial deposits that are commonly located in valley bottoms, depressions in bedrock or glaciated uplands, and along rivers and lakes.

- High soft ground amplification impact was assigned to areas indicated to be underlain by Holocene (non-glacially overridden) peat and bogs.

- No soft ground amplification impact was assigned to all other areas.

Tsunami and Seiche Impact Levels – Earthquake-induced flooding may result from tsunami or seiche waves from open (i.e., oceans) or closed (e.g., lake, reservoir) water bodies. As no significant open or closed water bodies exist along the alternative alignments, flooding due to tsunami or seismic seiche is not a risk.

Fault Ground Rupture Impact Levels – Fault ground surface rupture occurs where movement on a fault propagates to the ground surface, resulting in permanent ground displacement across the fault. It is unlikely that ground surface rupture on either the Seattle or South Whidbey Faults would affect the project corridor due to the distance between the corridor and the faults (8 miles). Furthermore, while movement apparently has occurred on these faults in the last 10,000 years, preliminary recurrence interval estimates for earthquakes that could cause ground rupture are on the order of 1,000 to 7,000 years. The three faults mapped within the project corridor do not show evidence of ground rupture for at least the last 13,500 to 15,000 years.

- High fault rupture hazard was assigned to areas along and adjacent to potentially active faults.

- Low fault rupture hazard was assigned to all other areas where unidentified faults could be present.

4.2.2 Seismic General Impacts

Liquefaction – Construction of the project generally would not affect the liquefaction susceptibility of the soil. Transmission line tower foundations built on soil that is susceptible to liquefaction could settle differentially and/or displace laterally during strong ground motion. Depending on the magnitude of movement and/or lateral spreading that occurs, the tower could be rendered unusable, or in extreme conditions, the tower could fail. Under these circumstances, additional maintenance and or repairs would be required, which could cause indirect environmental impacts.

Soft Ground Amplification – Towers or substation structures that are founded on soft ground could be subjected to amplified ground motions during an earthquake, causing damage to or failure of the structure. Soft ground amplification related damage could have indirect environmental impacts caused by additional maintenance work and or construction of new towers damaged during an earthquake.

Soft ground is not present along the alternatives and the Echo Lake Substation expansion area. Therefore, the planned structures would be in low soft ground amplification hazard areas.

Fault Ground Rupture – If an unidentified active fault is present at a tower location and the fault ruptures, the tower could be damaged or fail, which could cause indirect environmental consequences during maintenance or repairs.

No potentially active faults have been identified in the project area; therefore, there are no high fault rupture hazard areas. Because unidentified faults could be present, the entire project area has a low fault rupture hazard.

4.2.3 Alternative 1 Seismic

4.2.3.1 Impacts

High liquefaction hazard may be present in some recent alluvial deposits along the Cedar River. The hazard would be greatest in saturated sand deposits, which are relatively uncommon. Most Cedar River alluvium is gravelly and cobbley, which tends to have a lower liquefaction hazard. We understand towers will not be located close to the Cedar River so that liquefaction should not be a concern.

Moderate to low liquefaction may be present in the recessional outwash sediments between the tap into the Schultz-Raver No. 2 line and the Cedar River, and for about 1/3 mile north of the Cedar River. Liquefaction only occurs in saturated cohesionless soil. Based on gravel pits that we observed close to the proposed alignment, the depth to groundwater is apparently relatively deep. These conditions tend to reduce the potential for liquefaction and reduce the likely damage that would occur if the soil does liquefy. In our opinion, the potential for liquefaction in the recessional outwash deposits is low.

No liquefaction hazard was identified along the remainder of the Alternative 1 alignment.

4.2.3.2 Mitigation

Liquefaction susceptible soil can be improved and/or foundations can be designed to resist liquefaction-related damage. We recommend conducting a site-specific subsurface study prior to final design and construction to evaluate the liquefaction susceptibility of structures that would be built in moderate liquefaction hazard areas.

4.2.3.3 Cumulative Impacts

No cumulative impacts would be associated with seismic hazards.

4.2.4 Alternative 2

Impacts, mitigation, cumulative impacts and unavoidable effects, irreversible or irretrievable commitments of resources for Alternative 2 would be essentially the same as along Alternative 1 (see Section 4.2.3).

4.2.5 Alternative 3

4.2.5.1 Impacts

Liquefaction hazard and consequent potential impacts would be the same as Alternative 1 (see Section 4.2.3.1) except as follows. High liquefaction hazard is present where Alternative 3 crosses Holocene alluvium near Taylor Creek (Sheet 3, Figure 3). Moderate to low liquefaction may be present in the recessional outwash sediments between Anacortes Road and the Cedar River, and for about ¼ mile north of the Cedar River. While geologic units with low to high liquefaction hazard are present, shallow groundwater required for liquefaction would be more likely for tower locations founded close to the river elevation, such as the low banks where Alternative 3 would cross the Cedar River. The Holocene alluvium near Taylor Creek is relatively high above the Cedar River. Therefore, we anticipate that groundwater would be relatively deep, and consequently the liquefaction hazard would be low.

4.2.5.2 Mitigation

Refer to measures under Alternative 1, Section 4.1.4.2.

4.2.5.3 Cumulative Impacts

Refer to measures under Alternative 1, Section 4.1.4.3.

4.2.6 Alternative 4A

Impacts, mitigation, cumulative impacts and unavoidable effects, irreversible or irretrievable commitments of resources for Alternative 4A would be essentially the same as along Alternative 1 (see Section 4.2.3).

4.2.7 Alternative 4B

Impacts, mitigation, cumulative impacts and unavoidable effects, irreversible or irretrievable commitments of resources for Alternative 4B would be essentially the same as along Alternative 1 (see Section 4.2.3).

4.3 Hydrology and Climate

4.3.1 Hydrology, Water Quality and Climate Impact Levels

4.3.1.1 Floodplain Impact Levels

Construction and development can directly impact floodplains by obstructing or changing floodwater channels, which could increase downstream flows and/or upstream flooding. Indirect impacts can occur when resources are degraded (e.g., vegetation is removed and soil is compacted) enough to lessen the ability of the floodplain to store excess water, which increases the chance that flooding will occur.

A floodplain impact would occur when structures or permanent access roads encroach on designated floodplains and increase the potential for flooding, or might cause loss of human life, personal property, or natural resources within the floodplain.

No impacts would occur where floodplains are avoided or spanned, or where standard mitigation would effectively eliminate impacts.

4.3.1.2 Water Quality Limited Water Bodies Impact Levels

The water quality limited water bodies impact is assigned as follows:

- High 303(d) water quality impact is assigned to any water body that is on the Washington State 303(d) list and is crossed by the proposed alternative routes.

- No 303(d) water quality impact was assigned to the remaining areas.

No 303(d) listed waters are currently present in the project area. However, all of the alternatives cross portions of the City of Seattle Cedar River Watershed, which supplies drinking water to the City of Seattle and some surrounding water districts.

4.3.1.3 Groundwater Impact Levels

Although there is no known wellhead protection program for the project area, residential wells do exist in this area. Groundwater impact is assigned as follows:

- High groundwater impact is assigned to areas within a 100-foot radius of groundwater wells.

- Moderate groundwater impact is assigned to private land where groundwater wells likely exist within ½-mile.

- Low groundwater impact was assigned to the remaining areas.

4.3.1.4 Wind Impact Levels

Table 7 of the Soil Survey of Snoqualmie Pass Area (USDA, 1992) and Table 2 in this report show windthrow hazard for each soil unit. Ratings of windthrow impacts were assigned based on these hazard ratings, which range from slight to severe. The ratings are based on soil characteristics that affect root development and the ability of the soil to hold trees firmly, as follows:

- High windthrow impact was assigned to soil units where many trees could be blown over by moderate or strong winds. One soil unit with severe windthrow hazard, Humaquepts silt loam, is present for a short distance where Alternatives 2 and 3 cross Anacortes Road.

- Moderate windthrow impact was assigned to soil units where some trees could be blown over by moderate or strong winds when the soil is wet. Moderate windthrow hazard is present across about half of the project area.

- Low windthrow impact was assigned to soil units where under normal conditions, no trees are blown over. Strong winds could damage some trees but no trees would be uprooted.

- No windthrow impact would be assigned only to areas that are not affected by the construction and maintenance of the proposed project.

4.3.2 Hydrology, Water Quality and Climate General Impacts

Floodplains and Flooding – The proposed transmission line construction, operation and maintenance would not occur in the narrow floodplains or narrow incised stream valleys. Therefore, there should be no impacts to floodplains. The following sections do not discuss floodplains further, because no impacts are anticipated.

Surface water runoff is typically more rapid from areas that have been cleared of large vegetation and/or have disturbed soil than it is from areas with a mature forest canopy and/or with undisturbed soil. The forest canopy intercepts and temporarily stores rainfall, much of which may evaporate. The remaining stored rainfall eventually reaches surface water or groundwater, but over a longer time than rain falling on unforested ground. Forested areas typically return more moisture to the atmosphere by evapotranspiration, which reduces the total amount of runoff, and thus, more runoff would occur more rapidly after an area is cleared.

Disturbed soil is generally less permeable than undisturbed soil. Therefore, rainfall is more likely to runoff directly to streams from areas of disturbed soil than from undisturbed soil where rainfall typically infiltrates. While these impacts would occur along ROW clearings, access roads, and in the substation, the total area affected is small in comparison to the watersheds they cross.

Water Quality – The proposed alternative transmission line routes cross the Cedar River, Raging River, Rock Creek, Taylor Creek, Steele Creek, and/or Canyon Creek. At this time, none of these water bodies are listed on the Washington State 303(d) water quality limited water bodies list for the project area. Therefore, no water quality limited water bodies would be affected by construction of a new transmission line and associated roads.

While 303d limited water bodies are not present in the project area, the construction, operation and maintenance of the project, and especially ROW clearing and access road construction, could impact streams and rivers. As discussed in the following paragraphs, most impacts would occur for a short time. Overall, construction, operation and maintenance impacts are expected to be low and localized. The impacts to water quality are related to the landslide and soil erosion impacts, which are discussed in Section 4.1.

Short term impacts to water quality would be associated with ground disturbance from ROW clearing, building access roads, foundations and towers, and stringing cables. Clearing, exposing and disturbing soil increases erosion, runoff, and the risk of sediment reaching surface waters. Access road construction requires complete vegetation removal and grading, which typically disturb more soil than ROW clearing. The impacts are most intense during and immediately after construction. Impact intensity would diminish as disturbed sites are stabilized and revegetated, which reduces runoff and erosion.

In the long term, increased clearing in the watershed could create foraging habitat that could attract deer, elk and other warm-blooded animals that are potential sources of pathogens and viruses such as giardia and cryptosporidium. Turbidity from subbasins included in the project area contribute to the turbidity in the Cedar River. The Cedar River Watershed Habitat Conservation Plan (SPU, 1999) found that road surface erosion may contribute significant amounts of fine sediment. The amount of erosion increases with increasing traffic volumes on the roads, such as during the construction phase of this project. To a small degree, the temperature of surface water could be affected by reductions in shade where the ROW clearing crosses streams.

Groundwater – Construction and maintenance activities generally would not directly or indirectly introduce contaminates into groundwater aquifers. The project should not affect the chemical or biological characteristics of groundwater in the area. However, uncontrolled accidental spills from construction fuels and lubricants could infiltrate into, and contaminate, the aquifers that provide groundwater for residences, such as in the community of Selleck. BPA commonly uses herbicides during maintenance activities in conjunction with concurrence of landowners.

Wind – Trees typically develop firmness against prevailing winds. However, logging can alter the speed and direction of wind against which the trees have developed firmness. In addition, trees typically shelter each other from winds; however, this sheltering effect is lost for trees exposed along the edges of clearcuts. Therefore, windthrow may be more likely along areas logged and maintained for the transmission line tower alignment. High winds can also affect the transmission line towers and conductors.

The main impacts from windthrow are loss of timber resources, possible damage to structures, and exposing soil to erosion. Section 4.1.2 describes soil erosion impacts.

Impacts related to ROW clearing likely would decrease in the first years after construction. New trees growing adjacent to the ROW clearing, and to some extent trees that survive windstorms following construction, would develop firmness against wind and resist windthrow in the long term.

4.3.3 Alternative 1

4.3.3.1 Impacts

Flooding – As discussed in Section 4.3.2, the proposed project would not affect floodplains. However, the ROW clearing and access road construction would increase the peak runoff and total annual runoff somewhat. These impacts would be most intense during and following construction. As brushy vegetation becomes well established in the ROW clearing, the impacts would decrease. Because the cleared area is small in comparison to the drainage basin, the peak and total amount of runoff would not be noticeable in the Cedar River, Raging River, and their major tributaries. As a result, the relative increase in peak flow in any one watershed would be minor and have only low to no impacts.

Water Quality – Construction-related landslides, soil erosion, ROW clearing activities, and permanent forest canopy removal along the ROW could affect water quality, as discussed in Section 4.3.2. Because Alternative 1 would follow the existing Raver-Echo Lake 500-kV line, new access road construction would be limited to improving the existing trunk access roads and new spur roads to the tower locations. Section 4.1.3.1 describes landslide and soil erosion impacts that could affect water resources. Most potential landslide and soil erosion impacts would be short term.

Surface water runoff containing fuel spills, herbicide runoff and other contaminants can reach the main stream discharging from the drainage basin. Two major drainage basins could be affected as follows. Approximately 4.4 miles of the new line would be within the Cedar River Watershed boundaries. About 5.3 miles of the new line would be in the upper Cedar River drainage basin and the remainder would be in the Raging River drainage basin.

From south to north, Alternative 1 crosses the Cedar River, Rock Creek, and three small tributaries of Rock Creek, two tributaries of the Raging River and the Raging River. The transmission line could cross numerous small streams that are not shown on maps. The banks of the Cedar River and the Raging River are relatively high, such that vegetation close to the stream could be left in place to preserve shade. However, where Alternative 1 crosses Rock Creek and its various tributaries, the ROW clearing would remove all trees. This clearing would expose the creek to more direct sunlight, possibly causing some increase in water temperature. The impacts from clearing would be most intense during and immediately following construction and would diminish as low-growing vegetation is established over the creek. However, long-term impacts would occur because of the reduction in shade from the forest canopy. The proposed transmission line will generally cross at an angle close to perpendicular to the streams, so that a relatively short distance of the stream (i.e., 150 to 200 feet) would be affected. The impacts should be small, because the ROW clearing would occur over a small portion of the creek channels. For example, approximately 600 feet of creek channel in the Rock Creek drainage would be in newly cleared ROW, which is less than 1 percent of the more than 60,000 feet of total channel length shown on the USGS 7 ½ minute topographic maps.

Alternative 1 would cross over a pond and wetland area near the center of Section 14, or about 1 mile south of the Echo Lake Substation. Most of this wet area is on the west side of the existing access road. Therefore, little disturbance should occur from construction, operation and maintenance of the proposed new line, which would be on the east side of the access road.

Groundwater – From the tap point of the Schultz-Raver No. 2 line north to the southern Cedar River Watershed boundary, near Pole Line Road, Alternative 1 crosses private land with several residences. These areas are designated as moderate groundwater impact, because the residences likely have groundwater wells for domestic use. Construction- and maintenance-related accidental fuel spills or use of herbicides could potentially affect groundwater quality. The remainder of Alternative 1 crosses low groundwater impact areas that probably do not currently have active groundwater use, including the Cedar River Watershed and private timberland.

Wind – No high windthrow impact areas have been identified along Alternative 1. Soil units that could cause moderate windthrow impact underlie approximately half of Alternative 1, and low windthrow impact soil units underlie the remainder of the alignment. The moderate windthrow impact areas are present along the northern two thirds of Alternative 1, beginning near the angle tower of the Raver-Echo Lake 500-kV line (Soil units 24, 216 and 255 through 258 on the Soil Map, Figure 5). Most of the private timber land north of Brew Hill has been recently clearcut, which essentially eliminates the windthrow hazard. Potential windthrow impacts could occur mainly in the Cedar River Watershed from the angle tower location north to about 3000 feet south of the crest of Brew Hill.

4.3.3.2 Mitigation

Water Quality – Most impacts to water quality will be from construction of roads and ROW clearing, followed by operation and maintenance of roads. Most of the impacts and mitigation measures would be related to soil erosion, as discussed in Section 4.1.3.2. In addition to those mitigation measures, the following measures could be used to reduce impacts on water quality:

- Preserve existing vegetation where practical, and especially adjacent to intermittent and perennial creeks and streams. Plant and encourage riparian vegetation that provides shade for streams and that also meets clearance requirements for the proposed transmission line.

- In the Cedar River Watershed, encourage low-growing vegetation that does not provide foraging habitat for warm-blooded animals such as deer and elk.

- Avoid construction in wetland areas, such as the ponds in Section 14.

- Gate roads to restrict access. While public access is currently not allowed in the Cedar River Watershed, similar restrictions should be imposed on access roads for portions of the alignment that are in the upper Cedar River drainage basin. This would include the area south of Pole Line Road.

- Avoid refueling and/or mixing hazardous materials where accidental spills could enter surface or groundwater.

- Use BMPs to prevent fuel spills and herbicide runoff from reaching streams.

- Avoid or mitigate water quality and fish habitat degradation. Design and maintain roads so that drainage from the road surface does not directly enter streams, ponds, lakes, or impoundments. Direct water off roads into vegetation buffer strips or control through other sediment-reduction practices. Restrict road construction to areas physically suitable based on watershed resource characteristics. While no new bridges or fords are anticipated across larger streams, such as Steele and Rock Creeks, some new roads may cross smaller tributaries to these creeks. At these locations, design stream crossings to avoid adverse impacts to stream hydraulics and deterioration of stream bank and bed characteristics.

Groundwater – BPA would design, construct and maintain the project to comply with local ordinances and laws, and state and federal water quality programs to prevent degradation of the quality of aquifers and not jeopardize their usability as a drinking water source. An on-site refueling plan and spill notification plan would be designed and implemented to protect groundwater quality. During construction and maintenance, refueling and/or mixing hazardous materials would be done in a manner and location that would reduce the potential for accidental spills to impact groundwater.

Prior to using herbicides for ROW maintenance, BPA would contact affected landowners to find out if they have concerns with the use of herbicides on or near their property. BPA's policy on herbicide use in the vicinity of domestic and public drinking water wells is to maintain a 165-foot buffer for any herbicide having a ground or surface water advisory and a 50-foot buffer for any other herbicide. Any herbicide used in construction, operation or maintenance of the proposed project, including the substation, would be EPA-approved and would be applied in accordance with the label instructions.

Wind – Structures and conductors would be designed to resist toppling and excessive sway, respectively. The ROW clearing plan would account for possible windthrow to prevent damage that could affect the transmission line, and potentially affect service or cause a fire. The transmission line would be inspected following severe windstorms to evaluate possible windthrow damage, so that appropriate remedial measures could be implemented as needed for safety and to prevent excessive soil erosion.

4.3.3.3 Cumulative Impacts

Although no waters are 303(d) listed within the project area, potential increases in sedimentation, temperature, or other 303(d) parameters could affect future listings. The potential cumulative impacts on water quality and fish and other habitat would occur mostly from soil disturbing activities, which are described in Section 4.1. In addition, many of the streams will contain populations of fish with special status that may be impacted by the proposed project.

Several impacts discussed in the previous section could affect fish habitat. These include changes in water temperature from clearing vegetation adjacent to stream channels, increased sedimentation, and increased peak runoff resulting from reduced evapotranspiration and interception in cleared areas, and reduced permeability on road surfaces.

4.3.3.4 Unavoidable Effects, Irreversible or Irretrievable Commitments of Resources

Impacts from roads and ROW clearing will diminish with time, but not completely. Therefore, during the project life, the long-term impacts described in the previous sections would continue. If the transmission line is abandoned, a mature forest canopy could develop, and unused road surfaces would slowly revegetate. Related geology and soils effects and commitments of resources are discussed in Section 4.1.

4.3.4 Alternative 2

4.3.4.1 Impacts

Flooding – The amount of ROW clearing and road construction along Alternative 2 would be similar to Alternative 1. Therefore the impacts would be similar to those described in Section 4.3.3.1.

Water Quality – Most construction-related landslides, soil erosion, ROW clearing activities and maintenance along Alternative 2 would be essentially the same as along Alternative 1. Therefore, the impacts should be similar with the following differences. The portion of Alternative 2 that does not coincide with Alternative 1 would require some additional road building. Section 4.1.3.1 describes landslide and soil erosion impacts that could affect water resources. Most potential landslide and soil erosion impacts would be short term.

Surface water runoff containing fuel spills, herbicide runoff and other contaminants can reach the main stream discharging from the drainage basin. Two major drainage basins could be affected as follows. Approximately 4.9 miles of the new line would be within the Cedar River Watershed boundaries. About 5.3 miles of the new line would be in the upper Cedar River drainage basin, while the remainder would be in the Raging River drainage basin.

Alternative 2 would cross the same streams as Alternative 1; however, the Cedar River crossing will be at a low bank. Therefore, all trees and high brush close to the stream would have to be removed. This clearing would expose the river to more direct sunlight possibly causing some increase in water temperature.

Groundwater – Alternative 2 passes east of the community of Selleck before proceeding north into the Cedar River Watershed. The portions of Alternative 2 near this community are designated as moderate groundwater impact areas because they likely use water wells for residential domestic use. Accidental construction- and maintenance-related fuel spills or use of herbicides likely would not directly impact these wells. However, contaminants could migrate in groundwater towards the wells if an accidental spill were to occur upgradient from the wells.

The groundwater gradient was not evaluated in this study. The remainder of Alternative 2 crosses low groundwater impact areas that probably do not currently have active groundwater use, including the Cedar River Watershed and private timberland.

Wind – From the tap point of the Schultz-Raver No. 2 line north to the angle tower on the existing Raver-Echo Lake 500-kV line, about half of Alternative 2 is underlain by soil units designated as moderate windthrow impacts (Soil units 111, 255 and 256 on the Soil Map, Figure 5). A soil unit that could cause a high windthrow impact is present for about 500 feet south of Anacortes Road (Soil unit 79 on the Soil Map, Figure 5). The area south of Anacortes Road was recently clearcut logged, which essentially eliminates the windthrow hazard. Therefore, potential windthrow impacts could occur mainly in the Cedar River Watershed from the angle tower location south for about 4,500 feet to near Rocky Road. Some of this portion of Alternative 2 includes some smaller clearcut areas where there would be no windthrow hazard.

North of the angle tower on the existing Raver-Echo Lake 500-kV line, Alternative 2 follows the same alignment as Alternative 1. Therefore, the windthrow impacts north of the angle tower would be the same as described in Section 4.3.3.1.

4.3.4.2 Mitigation

Refer to measures under Alternative 1, see Section 4.3.3.2.

4.3.4.3 Cumulative Impacts

Refer to measures under Alternative 1, see Section 4.3.3.3.

4.3.4.4 Unavoidable Effects, Irreversible or Irretrievable Commitments of Resources

Refer to effects and commitments under Alternative 1, see Section 4.3.3.4).

4.3.5 Alternative 3

4.3.5.1 Impacts

Flooding – The amount of ROW clearing and road construction along Alternative 3 would somewhat greater than along Alternative 1. However, the total disturbed area is small in comparison to the drainage basins; therefore the impacts would be similar to those described in Section 4.3.3.1.

Water Quality – Most construction-related landslides, soil erosion, ROW clearing activities and maintenance along Alternative 3 will be essentially the same as along Alternative 1. Therefore, the impacts would be similar with the following differences. All of Alternative 3 would be on new ROW, such that additional access road would be required, increasing potential impacts on water quality. Most potential landslide and soil erosion impacts would be short term. Section 4.1.3.1 describes landslide and soil erosion impacts that could affect water quality.

Surface water runoff containing fuel spills, herbicide runoff and other contaminants can reach the main stream discharging from the drainage basin. Two major drainage basins could be affected as follows. Approximately 5.3 miles of the new line would be within the watershed boundaries. About 5.6 miles of the new line would be in the upper Cedar River drainage basin, while the remainder would be in the Raging River drainage basin.

Alternative 3 would cross the Cedar River at a low bank location so that trees and high brush close to the stream would have to be removed. This clearing would expose the creek to more direct sunlight, possibly causing some increase in water temperature. Alternative 3 crosses other streams including Taylor Creek, Steele Creek, the Raging River headwater creek, Canyon Creek, and three tributary creeks of the Raging River. Clearing along these streams may also cause increases in temperature, although the impacts should be low because of the short length of channel affected.

Groundwater – Alternative 3 does not cross private land where groundwater wells may be present. Therefore, the entire alignment is in a low groundwater impact area.

Wind – The soil units that underlie Alternative 3 for the first 6,000 feet north from the tap point of the Schultz-Raver No. 2 line are designated as moderate and high windthrow impacts (Soil units 216 and 255 {moderate}, and 79 {high} on the Soil Map, Figure 5). Much of this area is south of Anacortes Road, which was recently clearcut logged, essentially eliminating the windthrow hazard. The soil unit that has a severe windthrow hazard is in this clearcut area.

Soil units designated as moderate windthrow impacts underlie most of Alternative 3 from the first proposed angle tower location northeast to the second proposed angle tower location (Soil units 254 and 111 on the Soil Map, Figure 5). Low windthrow hazard is present from the Cedar River crossing north to the Cedar River Watershed boundary. The remainder of Alternative 3 extending north to the Echo Lake Substation crosses soil units that could have moderate windthrow hazard (Soil units 54, 163, and 255 through 258 on the Soil Map, Figure 5). This area has been clearcut logged in the past, although considerable regrowth has occurred in some areas.

4.3.5.2 Mitigation

Refer to measures under Alternative 1, see Section 4.3.3.2.

4.3.5.3 Cumulative Impacts

Refer to measures under Alternative 1, see Section 4.3.3.3.

4.3.5.4 Unavoidable Effects, Irreversible or Irretrievable Commitments of Resources

Refer to effects and commitments under Alternative 1, see Section 4.3.3.4).

4.3.6 Alternative 4A

4.3.6.1 Impacts

Flooding – The amount of ROW clearing and road construction along Alternative 4A would be similar to Alternative 1. Therefore, the impacts would be similar to those described in Section 4.3.3.1.

Water Quality – Most construction-related landslides, soil erosion, ROW clearing activities and maintenance along Alternative 4A will be essentially the same as along Alternative 1. Therefore, the impacts would be similar with the following differences. Additional access road building and maintenance would be required along the portions of Alternative 4A that do not coincide with Alternative 1. Most potential landslide and soil erosion impacts would be short term. Section 4.1.3.1 describes landslide and soil erosion impacts that could affect water resources.

Surface water runoff containing fuel spills, herbicide runoff and other contaminants can reach the main stream discharging from the drainage basin. Two major drainage basins could be affected as follows. Approximately 5.4 miles of the new line would be within the watershed boundaries. About 5.8 miles of the new line would be in the upper Cedar River drainage basin, while the remainder would be in the Raging River drainage basin.

Alternative 4A would cross the same streams as Alternative 1, with the Cedar River crossing at the same high bank location. Therefore, the impacts at the stream crossings would be the same as along Alternative 1.

Groundwater – Alternative 4A includes the portion of Alternative 2 that east of the community of Selleck before proceeding northwest into the Cedar River Watershed. Section 4.3.4.1 describes potential impacts in this area. The remainder of Alternative 4A crosses low groundwater impact areas that probably do not currently have active groundwater use, including the Cedar River Watershed and private timberland.

Wind – Soil units designated as low windthrow hazard underlie the segment of Alternative 4A that connects between Alternatives 1 and 2. The remainder Alternative 4A is described in Sections 4.3.2.1 and 4.3.3.1, where the alignment coincides with Alternatives 1 and 2, respectively.

Potential windthrow impacts could occur because of ROW clearing for the proposed transmission lines and to a lesser extent, clearing for access roads as described in Section 4.3.2.

4.3.6.2 Mitigation

Refer to measures under Alternative 1, see Section 4.3.3.2.

4.3.6.3 Cumulative Impacts

Refer to measures under Alternative 1, see Section 4.3.3.3.

4.3.6.4 Unavoidable Effects, Irreversible or Irretrievable Commitments of Resources

Refer to effects and commitments under Alternative 1, see Section 4.3.3.4).

4.3.7 Alternative 4B

The impacts, mitigation, cumulative impacts, and unavoidable effects, irreversible or irretrievable commitments of resources for Alternative 4B would be essentially the same as along Alternative 4A. The primary differences are the total length of the alignment is longer, more area in the Cedar River Watershed would be disturbed by ROW clearing, and Pole Line Road would serve as the trunk road where Alternative 4B does not coincide with Alternatives 1 or 2. Approximately 6.0 miles of the new line would be within the watershed boundaries. About 6.4 miles of the new line would be in the upper Cedar River drainage basin, while the remainder would be in the Raging River drainage basin.

Chapter 5 Environmental Consultation, Review and Permit Requirements

The specific permits/reviews that will likely be involved in this project include:

- Army Corps of Engineers (Corps) – Section 404. The Corps Section 404 review process is required for projects involving discharges of dredged or fill materials into the waters of the U.S., including wetlands and streams. Any proposed work located within a jurisdictional wetland and/or below the ordinary high water mark of a stream will require a nationwide permit (NWP) or an individual permit from the Corps. Nationwide permits that may apply to this project include: (1) NWP 7 for outfall structures and maintenance, (2) NWP 12 for utility line activities, and (3) NWP 39 for wetland fills that would not be covered in NWP 12.

- National Marine Fisheries Service (NMFS) and United States Fish and Wildlife Service (USFWS) – Endangered Species Act compliance. If the project has a federal nexus (actions authorized, funded, or carried out by federal agencies), a biological evaluation/assessment of the project area would be required to determine whether this project will affect Endangered Species Act (ESA) species or their habitat. Based on the findings of the biological evaluation/assessment, either informal or formal consultation will be required with NMFS and/or USFWS.

- Ecology – Section 401 Water Quality Certification and Coastal Zone Management Consistency. Section 401 Water Quality Certification and a Coastal Zone Management Consistency determination, issued by Ecology may be required as a condition of the Section 404 Nationwide permits for the proposed project. Some general requirements for Section 401, if it is required, include pollution spill prevention and response measures, disposal of excavated or dredged material in upland areas, use of fill material that does not compromise water quality, equipment fueling and washwater discharge restrictions, clear identification of construction boundaries, and site access to permitting agency for inspection.

  If Coastal Zone Management Consistency is required, a brief project description, assessment of project impacts and a statement of whether the project complies with the Coastal Zone Management Program will be required for Ecology's review. If the project is consistent with the Coastal Zone Management Program, Ecology will concur in writing.

- Ecology – Section 303(d). The proposed transmission line routes cross the following water bodies in the project area: Cedar River, Raging River, Rock Creek, Taylor Creek, Steele Creek, and Canyon Creek. At this time, none of these water bodies are listed on the Washington State 303(d) water quality limited water bodies list for the project area (the Cedar River is listed for fecal coliform further west of the project area). Therefore, a 303(d) review most likely will not be required.

- Ecology – Section 402 NPDES Permit to Discharge Stormwater During Construction Activity. The clearing, grading, and/or excavating activities involved with this project are expected to disturb more than 1 acre and would discharge stormwater from the project area into surface water. Land disturbing activities of 1 or more acres require a NPDES

General Permit to Discharge Stormwater associated with construction activity from Ecology. The purpose of this permit is to reduce stormwater pollution from construction activities.

The application for this permitting process is referred to as a Notice of Intent (NOI) and must be submitted to Ecology at least 38 days prior to the start of construction activities. At the time of application, the permittee must also publish a notice in the newspaper that has general circulation within the county in which the project is to take place.

Prior to granting the permit, the applicant must prepare a Stormwater Pollution Prevention Plan (SWPPP) for the project. The SWPP must include Temporary Erosion and Sedimentation Control (TESC) and Spill Control Containment and Countermeasures (SPCC) plans. The SWPPP is not submitted to Ecology, but is required to be kept on site during construction activities and made available to Ecology and local government agencies upon request.

- <u>Washington State Department of Fish and Wildlife (WDFW) – Hydraulic Permit Approval (HPA).</u> A HPA issued by the WDFW is required for any project that uses, diverts, obstructs, or changes the natural flow or bed of any fresh water in the state. General plans for the overall project and complete plans and specifications of the proposed construction are required for the permit submittal. The plans and specifications must include provisions for the proper protection of fish life.

- <u>Washington State Department of Natural Resources (DNR) – Forest Practice Application (FPA).</u> A FPA is required when harvesting timber, constructing roads or applying forest chemicals. The FPA must address road design and layout, and drainage features. The FPA must also address property ownership, harvest plans, and sensitive areas needing protection.

- <u>King County Department of Development and Environmental Services (DDES) – Grading Permit and Environmentally Sensitive Areas Review.</u> A clearing and grading permit is generally required for any earth disturbing project in which:

  1) Cumulative filling and excavating of 100 cubic yards or more;
  2) Filling to a depth of 3 feet or more;
  3) Excavating to a depth of 5 feet or more; or
  4) Clearing, filling or grading in a shoreline area, on steep slopes, in wetlands, or into or next to any body of water or sensitive area.

  One of many exceptions to this requirement is if the clearing and grading occurs in Class II, III or IV Special Forest Practice in a F (Forestry) zone and conducted in accordance with RCW 76.09 and WAC 22. The proposed project appears to lie entirely within a Forestry Production Zone.

  King County will review the proposed project for compliance with the Environmentally Sensitive Areas Ordinance in conjunction with their grading permit review. Environmentally sensitive areas in the project area could include wetlands, streams, flood hazards, erosion hazards, landslide hazards, seismic hazards, coal mine hazards, steep slope hazards, and/or volcanic hazards.

- <u>Wellhead Protection Program.</u> Although there is no known wellhead protection program for the project area, residential wells do exist in this area. Regulatory agencies may require an on-site refueling plan and spill notification plan for this project to protect groundwater quality. Manual tree removal instead of pesticide application may also be required in some areas.

Chapter 6 Individuals and Agencies Consulted

During the course of this study, the following agencies were consulted, either by direct telephone conversations, web sites, or policy publications:

Seattle Public Utilities
King County DDES
Kelly Peterson, Environmental Engineer, City of Kent Wellhead Protection Program
Washington State Department of Natural Resources
Washington State Department of Ecology, Water Quality Program

Chapter 7 Project Study Methods

The objective of this study was to evaluate the geologic, soil, hydrologic and climatic conditions that could be affected by, or could affect, the siting, design, construction, and maintenance of the proposed project. This objective was met by accomplishing the following items of work:

1. **Data Gathering.** Existing available information was collected from government agencies, private companies, and public libraries. The data included:

   - U.S. Geologic Survey (USGS) topographic maps
   - USGS geologic maps and reports
   - USGS seismologic studies
   - Aerial photographs (U.S. Bureau of Land Management and private)
   - U.S. Department of Agriculture soil maps
   - U.S. Forest Service and private timber company soil maps
   - Washington State Department of Natural Resources Division of Geology and Earth Resources maps and charts
   - Private timber company Watershed Analyses studies
   - BPA and Seattle Public Utilities (SPU) geographic information system (GIS) files and maps for the project area
   - Digital orthophoto maps for the project area
   - The Cedar River Municipal Watershed Habitat Conservation Plan by the USFWS

2. **Data Compilation**. The geologic, soil, hydrologic and wind data were compiled and plotted on GIS base maps provided by BPA.

3. **Aerial Photograph Analyses**. We interpreted and mapped geologic features along the alternative routes using stereo pairs of aerial photographs. This mapping focused on identifying features such as landslides, chronic erosion areas, floodplains, and organic soils, using the following aerial photographs:

Date Flown	Color	Approximate Scale	Flight	Source
July 1999	Color	1:25,600	BPA-REL	BPA
June 1995	Black and White	1:12,000	NW-95	WA DNR
August 1983	Infrared	1:48,000	HAP 83F	US ASCS
October 1971	Infrared	1:60,000	NASA 189	NASA
August 1970	Black and White	1:12,000	KP-70	WA DNR
July 1965	Black and White	1:60,000	WF	Pacific Aerial Surveys

WA DNR Washington State Department of Natural Resources
US ASCS United States Agricultural Stabilization and Conservation Service
NASA United States National Aeronautics and Space Administration

4. **Helicopter Overflight**. Following the aerial photographic interpretation and mapping, we flew over each alternative route at low altitude to observe the landforms and ground conditions.

5. **Ground Verification**. Following the aerial photographic interpretation and helicopter overflight, we visited selected locations to verify features identified from the published data and from the aerial photographs. This ground verification concentrated on features such as deeply incised ravines, landslides, erosional areas, apparent soft soil areas, and sensitive water resources.

6. **Technical Report**. The findings of this study are documented in this technical report.

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Glossary

100-year Floodplain – Areas that have a 1 percent chance of being flooded in a given year. (See **Floodplain**.)

Alluvial – Formed by flowing water.

Access road – Roads constructed to each structure site, first to build the tower and line, and later to maintain and repair it. Access roads are built where no roads exist. Where county roads or other access is already established, access roads are built as short spurs to the structure. Access roads are maintained even after construction.

Advance outwash – Glacial outwash that is deposited by, and in front of, an advancing glacier and is subsequently overridden by the glacier. Advance outwash deposits are overconsolidated and typically are very dense.

Alluvium – Clay, silt, sand, gravel, or similar material deposited by running water.

Alternatives – Refers to different choices of means to meet the need for action.

Andesite – A moderate-colored volcanic rock containing iron and magnesium minerals and quartz. Andesite is usually derived from Cascade volcanoes.

Anticline – A convex-up fold, the core of which contains stratigraphically older rocks.

Aquifer – Water bearing rock or sediment below the ground surface.

Basalt – A dark-colored volcanic rock containing iron and magnesium minerals, usually covering an extensive area.

Bedding (geologic) – The arrangement of a sedimentary deposit or rock in beds or layers of varying thickness and character.

Bedrock – The solid rock that underlies the soil and other unconsolidated material that is exposed at the surface.

Best management practices (BMP) – A practice or combination of practices that are the most effective and practical means of preventing or reducing the amount of pollution generated by non-point sources to a level compatible with water quality goals.

BPA – Bonneville Power Administration

Breccia – A coarse-grained clastic rock composed of large (greater than sand-sized), angular, and broken rock fragments that are cemented together in a finer-grained matrix. Breccia is similar to conglomerate except that most of the fragments have sharp edges and unworn corners.

Clast - An individual constituent, grain, or fragment of a sediment or rock, produced by the disintegration of a larger rock mass.

Clastic – Pertaining to or being a rock or sediment composed principally of clasts that have been transported individually for some distance from their places of origin.

Claystone – An indurated clay having the texture and composition, but lacking the fine lamination of shale.

Coal – A readily combustible rock containing more than 50 percent by weight and more than 70 percent by volume carbonaceous material that was formed from compaction and induration of plant remains similar to those in peat.

Cohesive – Said of a soil that has relatively high shear strength when wet, e.g., a clayey soil.

Cohesionless – Said of a soil that has relatively low shear strength when air-dried, e.g., a sandy soil.

Colluvial soil, Colluvium – Rock and soil accumulated on or at the foot of a slope.

Conductor – The wire cable strung between transmission towers through which electric current flows.

Conformable – Said of strata or stratification characterized by an unbroken sequence in which the layers are formed one above the other in parallel order. Contrasts with unconformable, in which a period of time is not represented by the strata during which erosion commonly occurred, forming and irregular surface.

Conglomerate – A coarse-grained clastic sedimentary rock composed of rounded fragments larger than 2 millimeters in diameter (granules, pebbles, cobbles, and boulders) set in a fine-grained matrix of sand, silt or cementing materials. The rock equivalent of gravelly soil deposits.

Consolidation – Gradual or slow reduction in volume and increase in density of soil or sediment in response to increased load or compressive stress.

Creep – The slow, continuous downslope movements of soil and rock under the influence of gravity.

Cross-bedding – The internal arrangement of the layers in a stratified rock, characterized by beds or laminae inclined at various angles to the principal bedding plane. It is produced by swift, local, changing currents of air or water. Especially characteristic of sandstone and sand deposits formed in dunes, stream channels and deltas.

Culvert – A corrugated metal or concrete pipe used to carry or divert runoff water from a drainage; usually installed under roads to prevent washouts and erosion.

Cumulative impact – Cumulative impacts are created by the incremental effect of an action when added to other past, present, and reasonably foreseeable future actions.

Current – the amount of electrical charge flowing through a conductor (as compared to voltage, which is the force that drives the electrical charge).

Cut and Fill – The process where a road is cut or filled on a side slope. The term refers to the amount of soil that is removed (cut) or added (fill).

Danger Trees – Trees or high growing brush in or alongside the ROW, which are hazardous to the transmission line. These trees are identified by special crews and must be removed to prevent tree-fall into the line or other interference with the wires. The owner of danger trees off the ROW is compensated for their value. BPA’s Construction Clearing Policy requires that trees be removed that meet either one of two technical categories: Category A is any tree that within 15 years will grow to within about 18 feet of conductors with the conductor at maximum sag (212^{o} F) and swung by 6 lb. per sq. ft. of wind (58 mph); Category B is any tree or high growing brush that after 8 years of growth will fall within about 8 feet of the conductor at maximum sag (176^{o} F) and in a static position.

DDES – King County Department of Development and Environmental Services.

Debris Flows – Rapid movement of water-charged mixtures of soil, rock, and organic debris.

Dextral shear – Shear movement, as occurs along a fault, where the movement of the side opposite an observer appears to have moved to the right.

Diabase – A dark colored intrusive igneous rock comprised essentially of the minerals labradorite and pyroxene.

Dike (geologic) – A long, narrow, crosscutting mass of igneous or eruptive rock intruded into a fissure in older rock.

DNR – Washington State Department of Natural Resources.

Easement – The grant of certain rights to use a piece of land (which then becomes a "right-of-way"). BPA acquires easement for many of its transmission facilities. This includes the right to enter the ROW to build, maintain, and repair facilities. Permission of these activities are included in the negation process for acquiring easements of private land.

Environmental Impact Statement (EIS) – A detailed statement of environmental impacts caused by an action, written as required by the National Environmental Policy Act.

Eocene – An epoch of the lower Tertiary period, lasting 21 million years , after the Paleocene (57.8 mybp) and before the Oligocene (36.6 mybp).

EPA – Environmental Protection Agency

Erosion – The process by which the surface of the earth is worn away by water, wind, glaciers, waves, etc.

ESCP – Erosion and Sediment Control Plan

EPA – Environmental Protection Agency

Evapotranspiration – The combined processes of evaporation and transpiration. Transpiration is the process by which plants take water from the subsurface, convey it through their woody parts, and give off water vapor through their leaves.

Fault (geologic) – A surface or zone of rock fracture along which there has been movement. The amount of movement can range from a few inches to miles.

Fault trace – The line formed where a fault intersects the ground surface.

FEMA – Federal Emergency Management Agency

Floodplain – The surface or strip of relatively smooth land adjacent to a river channel, constructed (or in the process of being constructed) by the present river in its existing regimen and covered with water when the river overflows its banks.

Fluvial – Of or pertaining to a river or rivers.

Footings – The supporting base for the transmission towers. Usually steel assemblies buried in the ground for lattice-steel towers.

Fore-arc – The zone in front (towards the ocean) of an island arc complex.

Formation – The basic stratigraphic unit used in the local classification of rocks that have some character (age, origin, composition) in common.

FPA – Forest Practice Application.

g – Acceleration due to gravity, equal to 9.8 meters/second/second (32.2 feet/second/second).

Gabbro – A dark colored, intrusive igneous rock composed chiefly of the minerals labradorite and augite.

GIS – Geographic Information Systems. A computer system that analyzes graphical map data.

Geotechnical – Pertaining to the properties of soil and rock, such as compaction, stabilization, compressibility, etc.

Glacial drift – A general term for sediment transported and deposited directly by glaciers.

Glacial erratic – A rock fragment carried by glacier ice and deposited when the ice melted some distance from the outcrop from which the fragment was derived. Generally of boulder size, although fragments range from pebbles to house-sized blocks.

Glacial outwash – Stratified sediment, consisting chiefly of sand and gravel, removed or "washed out" from a glacier by meltwater streams and deposited in front of or beyond the terminal moraine or the margin of an active glacier.

Glacial till – Unsorted and unstratified glacial drift deposited directly by and underneath a glacier without subsequent reworking by water from the glacier. Glacial till typically consists of a heterogeneous mixture of clay, silt, sand, gravel, cobbles and boulders that vary widely in size and shape.

Glaciofluvial – Pertaining to the meltwater streams flowing from wasting glacier ice, and especially to the deposits and landforms produced by such streams.

Glaciolacustrine – Pertaining to, derived from or deposited in glacial lakes. Also said of the deposits and landforms composed of suspended material brought by meltwater streams flowing into lakes bordering a glacier.

Glaciomarine – Said of marine sediments that contain glacial material. Similar to glaciolacustrine, except related to marine water that borders a glacier, and containing clastic debris.

Groundwater – The water beneath the surface of the ground. Typically, groundwater occurs in the small pores between grains of soil or in rock.

Group – A major rock stratigraphic unit next higher in rank than formation. Consists of two or more associated formations.

Headwater – The source (or sources) and upper part of a stream, including the upper drainage basin.

Holocene – The upper epoch of the Quaternary period, from the end of the Pleistocene to present time. Sometimes referred to as "Recent".

HPA – Hydraulic Permit Approval.

Hydrogeology – The science that deals with subsurface waters and related geologic aspects of surface waters.

Hydrology – The science dealing with the properties, distribution, and circulation of water.

Ice-contact drift – Stratified glacial drift deposited in contact with melting glacier ice. Normally marked by numerous kettles and hummocky ground.

Indurated – Said of a compact rock or soil hardened by the action of pressure, cementation and heat.

Intermittent – Referring to periodic water flow in creeks or streams.

Intraslab earthquakes – Earthquakes that originate within a subducting slab, or plate, as opposed to originating on the slab or plate boundaries (interslab).

Interglacial – Refers to a period of time when glaciers were not present and between glacial advances.

Intrusive igneous rock – Rock formed when molten rock (magma) is injected into existing rock. The intrusive body can range from a narrow dike or sill to a body that is miles across.

Island arc complex – A generally curved linear belt of volcanoes above a subduction zone, and the volcanic (extrusive) and plutonic (intrusive) rocks formed there.

Kettle (geologic) – A steep sided, usually basin- or bowl-shaped hole or depression without surface drainage in glacial drift deposits. Commonly contains a lake, pond or swamp. Formed by the melting of a large block of stagnant ice (left behind after a retreating glacier) that had been wholly or partly buried in the glacial drift.

kV – kilovolt, one thousand volts

Landform – Any physical, recognizable form or feature of the Earth's surface, having a characteristic shape, and produced by natural causes. It includes major forms such as a plain, plateau, mountain, slope or dune, among others.

Landslide – Any mass movement process characterized by downslope movement of soil and rock, by means of gravity; or the resulting landform. Can also include other forms of mass wasting not involving sliding, e.g. rockfall. The terminology designating particular landslide types generally refers to the landform as well as the process responsible for the landform, e.g. deep-seated landslide, earth flow, etc.

Lattice steel – Refers to a transmission tower constructed of multiple steel members that are connected together to make up the frame.

Liquefaction – The phenomenon in which saturated, cohesionless soils are temporarily transformed into a near liquid or "quick-sand" state. During an earthquake, ground shaking may result in a buildup of pore water pressure in the saturated soil to a point where the pore water pressure approaches the grain-to-grain contact pressure. As this occurs, the soil particles begin to loose contact with each other and the soil liquefies.

Loamy – A soil whose texture and properties are intermediate between a coarse-texture or sandy soil and a fine-textured or clayey soil.

Lodgment till – A very dense glacial till containing a distribution of all soil particles, from clay to boulders, formed beneath a moving glacier and deposited upon bedrock or other glacial deposits. Commonly characterized by fissile structure (capable of being split easily along closely spaced planes) and stones oriented with their long axes generally parallel to the direction of ice movement.

Low-gradient – With gentle slopes.

Magnitude (earthquake) – A measure of the strength of an earthquake or the strain energy released by it, as determined by seismographic observations.

Mass movement – The dislodgment and downhill transport of soil and rock materials under the direct influence of gravity. Includes movements such as creep, debris torrents, rock slides, and avalanches.

Mass wasting – A general term for the dislodgment and downslope transport of soil and rock material under gravitational forces. It includes slow displacements such as soil creep and rapid movements such as earthflows, rockfalls and avalanches.

Miocene – An epoch of the upper Tertiary period, lasting 18.4 million years, after the Oligocene (23.7 mybp) and before the Pliocene (5.3 mybp).

Mitigation – Steps taken to lessen the effects predicted for each resource, as potentially caused by the transmission project. They may include reducing the impact, avoiding it completely, or compensating for the impact. Some mitigation, such as adjusting the location of a tower to avoid a special resource, is taken during the design and location process. Other mitigation, such as reseeding access roads to desirable grasses and avoiding weed proliferation, is taken after construction.

mybp – million years before present

NMFS – National Marine Fisheries Service.

NOI – Notice of Intent.

Nonrenewable – Not capable of replenishing.

Normally consolidated – Soil and sedimentary deposits that are consolidated in equilibrium with the overburden pressure.

NPDES – National Pollutant Discharge Elimination System.

NRCS – National Resource Conservation Service (formerly Soil Conservation Service).

NWP – Nationwide permit.

Oligocene – An epoch of the lower Tertiary period, lasting 12.9 million years, after the Eocene (36.6 mybp) and before the Miocene (23.7 mybp).

Outcrop – An area where rock is exposed at the Earth's surface.

Overconsolidated – Said of soil and sedimentary deposits that are consolidated greater than normal for the existing overburden pressure. Commonly caused by large overburden pressures that have subsequently been removed. Soil and sedimentary deposits that were overridden by glacier ice are typically overconsolidated.

Peak ground acceleration – The maximum instantaneous ground acceleration caused by an earthquake.

Perennial – Streams or creeks with year-round water flow.

Permeability – The ease with which a fluid will move through a porous medium, such as rock or soil.

Physiographic province - A region all parts of which are similar in geologic structure and climate and which has consequently had a unified geomorphic history; a region whose pattern of relief features or landforms differs significantly from that of adjacent regions.

Plate tectonics – Global tectonics base on an Earth model characterized by a small number (10-25) of large broad thick plates (blocks composed of continental and oceanic crust and mantle) each of which floats on a viscous underlayer in the mantle and move more or less independently of the other plates. At their margins, plates move away from each other at sea-floor spreading centers where new oceanic crust is created, move towards each other where one plate is subducted below the other, or move next to each other along a strike-slip fault.

Pleistocene – An epoch of the Quaternary, lasting 2 million years, after the Pliocene (2 mybp) and before the Holocene (0.01 mybp).

Quaternary – The second period of the Cenozoic era (following the Tertiary) thought to cover the last two or three million years; includes the Pleistocene and Holocene epochs.

Rainsplash erosion – Erosion that occurs when raindrops impact bare soil and incorporate soil particles in the water that splashes. On a slope, more of the rainsplash moves downslope, resulting in a net downslope soil movement.

Ravel – The downslope movement of single, granular particles, usually as a result of result of gravity.

Ravine – A small, narrow, deep, steep-sided depression, less precipitous than and not as grand as a gorge, smaller than a canyon but larger than a gully. Usually carved by running water.

Recessional outwash - Glacial outwash deposited by a receding glacier. Recessional outwash deposits are normally consolidated and typically are loose to medium dense.

Redd – nest of salmonid eggs deposited in a gravel pocket.

Residual soil, residuum – An accumulation of rock debris and soil formed by weathering and remaining essentially in place as a thin surface layer over the underlying parent material.

Right-of-way (ROW) – An easement for a certain purpose over the land of another, such as a strip of land used for a road, electric transmission line, pipeline, etc.

Rill – A rill is a very small channel made by a small stream (commonly ephemeral).

Riprap – Broken stones put in areas to prevent erosion, especially along river and stream banks.

Sandstone – Sedimentary rock consisting usually of quartz sand, but also feldspar or basalt, united by some cementing agent.

Sediment – Solid fragmental material or mass of such material, either inorganic or organic, that originates from weathering rocks and is transported by, suspended in, or deposited by air, water, or ice and that forms in layers on the Earth's surface.

Sedimentary – Pertaining to or containing sediment.

Sedimentation – The process of forming or accumulating sediment in layers.

Seiche – A seismically-induced wave that forms on a lake or other closed body of water. Similar to a tsunami but restricted to a closed body of water.

Seismic – Earthquake activity.

Seismogenic – Said of a fault or zone that is capable of generating earthquakes.

Shale – A fissile rock that is formed by the consolidation of clay, mud, or silt, has a finely stratified or laminated structure, and is composed of minerals essentially unaltered since deposition.

Sill (geologic) – A tabular body of igneous intrusion that parallels the planar structure of the surrounding rock. Similar to a dike, except that the orientation of a dike cuts across the planar structure of the surrounding older rock.

Siltstone – A rock composed chiefly of indurated silt.

Single-circuit – A line with one electrical circuit on the same tower.

Slash – Debris left over from harvesting trees.

Slump – Deep, rotational landslide, generally producing coherent movement (back rotation) of blocks over a concave failure surface. Typically, slumps are triggered by the buildup of pore water pressure in mechanically weak materials (deep soil or clay-rock rock).

Soil – All earthy material overlying bedrock.

SPCC – Spill Control Containment and Countermeasures.

SPU – Seattle Public Utilities

Stratified – Formed, arranged, or laid down in layers or strata; especially said of any layered sedimentary rock or deposit.

Stratigraphy – The branch of geology dealing with the classification, correlation and interpretation of stratified rocks.

Structure – Refers to a type of support used to hold up transmission or substation equipment.

Subduction zone – An elongate region along which a crustal block of the earth's surface descends relative to another crustal block.

Subcrustal intraslab earthquake – An earthquake that occurs within a subducting plate beneath the crustal plate.

Substation – The fenced site that contains the terminal switching and transformation equipment needed at the end of a transmission line.

Substation rock surfacing – An 8-cm (3-in.) layer of rock selected for its insulating properties is placed on the ground within the substation to protect operation and maintenance personnel from electrical danger during substation electrical failures.

Swale – A low-lying or depressed and sometimes wet stretch of land.

SWPPP – Stormwater Pollution Prevention Plan.

Syncline – A concave-up fold, the core of which contains stratigraphically younger rocks.

Talus – Rock debris that has accumulated at the base of a cliff or steep slope.

Tap – The point at which a transmission line is connected to a substation or other electrical device to provide service to a local load.

Tectonics – A branch of geology concerned with the structure of the crust of a planet (as earth) with the formation of folds and faults in it.

Terrace – An old plain of various origins, ordinarily flat or undulating that borders a river, lake or the sea.

Tonalite – a light colored intrusive igneous rock similar to granite.

Tower – See **Structure**.

Transmission line – The structures, insulators, conductors, and other equipment used to transmit electrical power from one point to another.

Tsunami – A gravitational sea wave formed by any large-scale, short-duration disturbance of the ocean floor, which commonly is an earthquake.

Turbidity – The state or condition or quality of opaqueness or reduced clarity of a fluid, due to the presence of suspended matter.

Upgradient – Refers to slope of the groundwater table. Upgradient is in the upslope direction and opposite to the direction of groundwater flow.

USC – Unified Soil Classification

USFWS – United States Fish and Wildlife Service

USGS – United States Geological Survey

USLE – Universal Soil Loss Equation

Vashon Stade – The middle of three stades of the last glaciation of the Puget Lowland; the most recent stade that reached the central Puget Lowland.

Volcanic – Pertaining to the activities, structures or rock types of a volcano.

Volcanic ash – Fine material formed by a volcanic explosion or aerial expulsion from a volcanic vent.

Volcaniclastic – Pertaining to clastic rocks, containing volcanic material in whatever proportions and without regard to its origin or environment.

Volcanic tuff – A compact deposit of volcanic ash and dust formed by a volcanic explosion or aerial expulsion from a volcanic vent. It may contain up to 50 percent of non-volcanic sediment.

Volt – The international system unit of electric potential and electromotive force.

Voltage – The driving force that causes a current to flow in an electrical circuit.

Water bars – Smooth, shallow ditches excavated at an angle across a road to decrease water velocity and divert water off and away from the road surface.

WDFW – Washington State Department of Fish and Wildlife.

Wetlands – An area where the soil experiences anaerobic conditions because of inundation of water during the growing season. Indicators of a wetland include types of plants, soil characteristics, and hydrology of the area.

Windthrow – The uprooting and tipping over trees by wind.

List of Preparers

Principal Investigators

William T. Laprade, C.E.G. — Engineering Geologist, Vice President

Responsible for geology and engineering geology review.

Education: B.A. and M.A. Geography, B.S. Geological Sciences, Post-Graduate Studies.

Experience: Engineering geology including landslides, tunnels, foundations, dams, and pipeline and roadway alignments; with Shannon & Wilson since 1973.

Christopher A. Robertson, P.E., C.E.G. — Geotechnical Engineer, Project Manager

Responsible for geotechnical engineering and project management.

Education: B.S. and M.S. Geology, M.S. Civil Engineering

Experience: 19 years of professional experience in geotechnical engineering, hydrogeology, slope stability, and seismic geotechnical engineering; with Shannon & Wilson since 1995.

Jeffrey R. Laird, C.E.G. — Principal Engineering Geologist

Responsible for field studies, geologic analysis, and report preparation.

Education: B.S. Geology, M.S. Geomorphology

Experience: 14 years of professional experience in geologic field mapping, erosion and sedimentation, and fluvial geomorphology and slope stability; with Shannon & Wilson since 1987.

Technical and Clerical Assistance

Judith A. Bloch	Librarian
Lori K. Doherty	Technical Assistant, word processing
T. Kenny Lilley	Office Clerk
Steven A. Mikulencak	Geologist, GIS technician
William J. Perkins, R.P.G	Geologist, Seismic Hazards Specialist
Becki Kniveton	Ecologist
Michelle Iaci	Word Processing
Katie Walter, P.W.S.	Wetland Biologist

TABLE 1: BONNEVILLE POWER ADMINISTRATION
KANGLEY - ECHO lAKE TRANSMISSION PROJECT GEOLOGIC DESCRIPTIONS

Map Unit	Description	Age	Soil/Rock Type	Structure and Bedding	Associated Hazards
QUATERNARY DEPOSITS					
Qa	Alluvium	Holocene	Cedar River: Well sorted pebble to cobble gravel and sand. Smaller streams: thin deposits of sand and gravel.	Very loose to medium dense. Stratified with cross bedding. May contain organic material.	Streambank erosion, ponding, high groundwater, flooding, siltation and potentially liquefiable; locally compressible.
Qb	Bog	Holocene	Organic sediment deposited mostly in closed depressions. The thickness is highly variable.	Very soft to medium stiff. Horizontally laminated, rooted and bioturbated.	Poor foundation material that can cause large differential foundation and/or road settlements. Fills potentially unstable. High groundwater and ponded water.
Qls	Landslide	Holocene to Pleistocene	Landslide debris composed of colluvium and/or creek bedrock	No sorting or structure, hummocky topography, and weak slip planes	Renewed ground movement, variable foundation strength, poor drainage. Excavations, erosion, fills, drainage modifications or removal of vegetation can reactivate movement.
Qvi	Ice Contact Deposits	Pleistocene	Pebbly sand and pebble-cobble gravel, with occasional boulders. Forms kames, kame terraces and eskers.	Loose to dense. Well sorted and stratified to poorly sorted and massive deposits.	Variable strength and drainage characteristics, low liquefaction potential. Scattered boulders may impede excavation.
Qvr	Glacial Outwash (Recessional)	Pleistocene	Sand, pebble-cobble gravel, and silty sand to silty clay.	Stratified, moderately to well sorted sand and gravel to well bedded silt and clay. Loose to dense, variable permeability.	Variable strength and drainage characteristics, cut slopes can ravel due to lack of cohesion, low liquefaction potential. Scattered boulders may impede excavation.
Qvt	Glacial Till	Pleistocene	Gravel and occasional boulders in a silty sand matrix. Glacial till deposits are typically 10 feet thick, but may be as thick as 50 feet.	Dense to very dense. Typically massive and unsorted to poorly sorted, may contain lenses of sand.	Typically high load-bearing characteristics, but high pore water pressure may exist in perched ground water or in confined sand lenses. Scattered boulders may impede

TABLE 1: BONNEVILLE POWER ADMINISTRATION
KANGLEY - ECHO lAKE TRANSMISSION PROJECT GEOLOGIC DESCRIPTIONS

Map Unit	Description	Age	Soil/Rock Type	Structure and Bedding	Associated Hazards
TERTIARY BEDROCK UNITS					
Tpg	Puget Group, undifferentiated	Middle to Late Eocene	Sandstone, siltstone, claystone and coal, deposited primarily in a fluvial environment.	Sandstone is generally massive to cross bedded. Occasional channel cut-and-fill structures. Fractures, joints, bedding planes and facies contacts.	Adversely oriented, interbedded weak rocks (coal, claystone), bedding planes and joints can form failure planes. High pore water pressures in perched groundwater. Massive rock may require blasting/hydraulic breakers.
Tpr	Renton Formation	Late Eocene	Sandstone, siltstone, claystone and coal deposited in fluvial and nearshore marine environments.	Fine-grained siltstone and claystone interbeds commonly form valleys between more resistant sandstone- capped ridges. Fractures, joints, bedding planes and facies contacts.	Adversely oriented, interbedded weak rocks (coal, claystone), bedding planes and joints can form failure planes. High pore water pressures in perched groundwater. Massive rock may require blasting/hydraulic breakers.
Tpt	Tukwila Formation	Middle to late Eocene	Volcanic lava flows, sills and dikes, tuff, and breccia, with sandstone and conglomerate interbeds.	Flow rocks are more resistant to erosion, and making up most Tukwila Formation outcrops. Fractures, joints, bedding planes and facies contacts.	Interbedded and fractured/jointed weak and strong rocks and zones of highly weathered rock form failure planes. Massive, fresh flow rocks may require blasting/hydraulic breaking.
Tptm	Tiger Mountain Formation	Late early to middle Eocene	Medium-grained sandstone with interbedded siltstone, conglomerate and coal beds.	Fine-grained siltstone interbeds commonly form valleys between more resistant sandstone- capped ridges. Fractures, joints, bedding planes and facies contacts.	Adversely oriented, interbedded weak rocks (coal, claystone), bedding planes and joints can form failure planes. High pore water pressures in perched groundwater. Massive rock may require blasting/hydraulic breakers.
Trr	Raging River Formation	Late early to Middle Eocene	Volcanic sandstone, siltstone and conglomerate deposited in a nearshore marine environment.	Fine-grained siltstone and claystone interbeds commonly form valleys between more resistant sandstone- capped ridges. Fractures, joints, bedding planes and facies contacts.	Adversely oriented, bedding planes and joints can form failure planes. High pore water pressures in perched groundwater. Massive rock may require blasting/hydraulic breakers.

TABLE 2: BONNEVILLE POWER ADMINISTRATION
KANGLEY - ECHO LAKE TRANSMISSION PROJECT SOIL UNIT DESCRIPTIONS

Map Unit	Name	Bedrock Depth (inches)	Erosion Factor, K	Slope %	Description	Erosion Hazard	Windthrow Hazard
10	Barneston gravelly coarse sandy loam	>60	0.15	0-6	Glacial outwash terraces and volcanic ash.	Slight	Slight
11	Barneston gravelly coarse sandy loam	>60	0.15	6-30	Glacial outwash terraces and volcanic ash.	Slight	Slight
12	Barneston gravelly coarse sandy loam	>60	0.15	30-65	Glacial outwash terraces, terrace escarpments and volcanic ash.	Moderate	Slight
17	Beausite gravelly loam	24-40 Hard	0.20	6-30	Glacial till and colluvium formed from sandstone.	Slight	Moderate
18	Beausite gravelly loam	24-40 Hard	0.20	30-65	Glacial till and colluvium formed from sandstone.	Moderate	Moderate
24	Blenthen gravelly loam	>60	0.24	30-65	Colluvium and slope alluvium formed from glacial drift. Some admixture of volcanic ash.	Moderate	Slight
41	Chuckanut loam	40-60 Soft	0.32	6-15	Mixture of volcanic ash and colluvium derived from sandstone and glacial till.	Slight	Slight
42	Chuckanut loam	40-60 Soft	0.32	15-30	Mixture of volcanic ash and colluvium derived from sandstone and glacial till.	Slight	Slight
43	Chuckanut loam	40-60 Soft	0.32	30-65	Mixture of volcanic ash and colluvium derived from sandstone and glacial till.	Moderate	Slight
45	Cinebar silt loam	>60	0.28	15-30	Loess and slope alluvium high content of volcanic ash.	Slight	Slight
53	Edgewick silt loam	>60	0.37	0-3	River terrace alluvium.	Slight	Slight
54	Elwell silt loam	>60	0.28	6-30	Weathered glacial till and volcanic ash.	Slight	Moderate
55	Elwell silt loam	>60	0.28		Weathered glacial till and volcanic ash.	Moderate	Moderate
63	Gallup loam	>60	0.32	6-30	Mixture of volcanic ash and weathered metasediments.	Slight	Slight
65	Gallup loam, breccia substratum	>60	0.32	30-65	Mixture of volcanic ash and colluvium derived from volcanic rock.	Moderate	Slight
71	Hartnit silt loam	20-40 Hard	0.24	8-30	Mixture of glacial till, volcanic ash, and colluvium derived from volcanic rock.	Slight	Moderate
79	Humaquepts silt loam, silty clay loam and gravelly, silty clay loam	>60	0.37	0-5	Alluvial terraces.	Slight	Severe

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KANGLEY - ECHO LAKE TRANSMISSION PROJECT SOIL UNIT DESCRIPTIONS

Map Unit	Name	Bedrock Depth (inches)	Erosion Factor, K	Slope %	Description	Erosion Hazard	Windthrow Hazard
95	Kaleetan sandy loam	>60	0.20	30-65	Mixture of volcanic ash and pumice over colluvium derived from tuff, breccia and glacial till.	Moderate	Slight
97	Kanaskat gravelly sandy loam	60-72 Soft	0.15	30-65	Mixture of volcanic ash, colluvium, and material weathered from extrusive rocks.	Moderate	Slight
111	Klaus sandy loam	>60	0.20	0-8	Mixture of volcanic ash and alluvium overlying glacial outwash.	Slight	Moderate
113	Klaus sandy loam	>60	0.20	30-65	Mixture of volcanic ash and alluvium over glacial outwash.	Moderate	Moderate
121	Littlejohn gravelly sandy loam	25-40 Hard	0.15	30-65	Mixture of volcanic ash and pumice overlying residuum and colluvium derived from volcanic rock.	Moderate	Moderate
124	Littlejohn gravelly sandy loam, tuff substratum	25-40 Hard	0.15	30-65	Mixture of volcanic ash and pumice overlying residuum and colluvium derived from volcanic rock.	Moderate	Moderate
146	Nargar fine sandy loam	>60	0.32	0-15	Mixture of volcanic ash and sandy alluvium over glacial outwash.	Slight	Slight
147	Nargar fine sandy loam	>60	0.32	15-30	Mixture of volcanic ash and sandy alluvium and glacial outwash terraces.	Slight	Slight
148	Nargar-Pastik complex	>60	0.32	35-70	Terrace escarpments of sandy alluvium and glacial outwash, and lake sediments mixed with volcanic ash.	Moderate	Slight
158	Norma loam	>60	0.37	0-3	Alluvium formed in depressions of glacial till.	Slight	Severe
159	Oakes gravelly loam	>60	0.24	6-30	Volcanic ash and colluvium and slope alluvium developed from glacial till.	Slight	Slight
162	Ogarty gravelly loam	20-40 Hard	0.20	8-30	Volcanic ash and colluvium and residuum developed from andesite and breccia.	Slight	Moderate
163	Ogarty gravelly loam	20-40 Hard	0.20	30-65	Volcanic ash and colluvium and residuum developed from andesite and breccia.	Moderate	Moderate
164	Ogarty-Rock outcrop complex	20-40 Hard	0.20	45-90	Mixture of volcanic ash and colluvium and residuum derived from volcanic rock.	Severe	Moderate

TABLE 2: BONNEVILLE POWER ADMINISTRATION
KANGLEY - ECHO LAKE TRANSMISSION PROJECT SOIL UNIT DESCRIPTIONS

Map Unit	Name	Bedrock Depth (inches)	Erosion Factor, K	Slope %	Description	Erosion Hazard	Windthrow Hazard
172	Ovall gravelly loam	20-40 Hard	0.17	15-30	Glacial drift mixed with colluvium and residuum derived from volcanic rock.	Slight	Moderate
188	Pitcher sandy loam	>60	0.28	8-30	Volcanic ash over colLuvium and residuum developed from andesite.	Moderate	Slight
189	Pitcher sandy loam	>60	0.28	30-65	Volcanic ash over colluvium and residuum developed from andesite.	Moderate	Slight
191	Pitcher sandy loam, tuff substratum	>60	0.28	8-30	Volcanic ash over colluvium and residuum derived dominantly from volcanic rock.	Slight	Slight
192	Pitcher sandy loam, tuff substratum	>60	0.28	30-65	Volcanic ash over colluvium and residuum derived dominantly from volcanic rock.	Moderate	Slight
200	Playco very gravelly loamy sand, tuff substratum	>60	0.10	30-65	Mixture of volcanic ash and pumice and colluvium derived dominantly from volcanic rock.	Moderate	Slight
203	Ragnar loam	>60	0.32	6-15	Glacial outwash.	Slight	Slight
206	Ragnar-Lynnwood complex	>60	0.32	30-45	Glacial outwash.	Moderate	Slight
211	Reichel silt loam	40-60 Hard	0.32	6-30	Mixture of volcanic ash and colluvium and residuum derived dominantly from volcanic rock.	Slight	Slight
212	Reichel silt loam	40-60 Hard	0.32	30-65	Mixture of volcanic ash and colluvium and residuum derived dominantly from volcanic rock.	Moderate	Slight
216	Rober loam	>60	0.32	0-30	Volcanic ash and glaciolacustrine sediments.	Slight	Moderate
237	Skykomish gravelly sandy loam	>60	0.10	0-30	Mixture of volcanic ash and glacial outwash.	Slight	Slight
244	Stahl very gravelly silt loam	20-40 Hard	0.10	30-65	Mixture of volcanic ash and colluvium and residuum derived dominantly from volcanic rock.	Moderate	Moderate
247	Sulsavar loam	>60	0.32	0-8	Mixture of volcanic ash and alluvium.	Slight	Slight
254	Tokul gravelly loam	>60	0.20	0-6	Mixture of volcanic ash and glacial till.	Slight	Moderate

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KANGLEY - ECHO LAKE TRANSMISSION PROJECT SOIL UNIT DESCRIPTIONS

Map Unit	Name	Bedrock Depth (inches)	Erosion Factor, K	Slope %	Description	Erosion Hazard	Windthrow Hazard
255	Tokul gravelly loam	>60	0.20	6-15	Mixture of volcanic ash and glacial till.	Slight	Moderate
256	Tokul gravelly loam	>60	0.20	15-30	Mixture of volcanic ash and glacial till.	Slight	Moderate
257	Tokul gravelly loam	>60	0.20	30-65	Mixture of volcanic ash and glacial till.	Moderate	Moderate
258	Tokul gravelly loam - Pastik silt loam	>60	0.32	45-90	Mixture of volcanic ash and glacial till and lake sediments.	Severe	Moderate
273	Welcome loam	40-60 Soft	0.28	0-30	Volcanic ash, colluvium and slope alluvium derived from sandstone and modified by glacial till.	Slight	Slight
274	Welcome loam	40-60 Soft	0.28	30-65	Volcanic ash, colluvium and slope alluvium derived from sandstone and modified by glacial till.	Moderate	Slight
278	Winston loam	>60	0.24	0-8	Volcanic ash and glacial outwash.	Slight	Slight

TABLE 3
COMPARISON OF IMPACTS ON ALTERNATIVES

Alternative	Length (miles)	Clearing[1] (acres)	Deep-[2] Seated Landslide (% of length)	Shallow[3] Landslide (% of length)	Soil Erosion (% of Length) Severe	Soil Erosion (% of Length) Moderate	Soil Erosion (% of Length) Slight	Stream Crossings[4]	Windthrow (% of Length) High	Windthrow (% of Length) Moderate
1	9.1	165	6	5	3	15	82	9	0	55
2	9.1	165	6	3	3	15	82	10	1	71
3	10.6	190	4	5	2	20	78	13	1	60
4A	9.6	175	6	5	3	15	82	10	1	60
4B	10.2	185	6	5	3	15	82	10	1	57

(1) Based on 150-foot wide corridor
(2) Moderate and low deep-seated landslide hazard areas
(3) Low shallow landslide hazard areas
(4) Based on intersection of alignment with streams mapped on 1973 Hobart, 1968 North Bend, and 1968 Eagle Gorge USGS 7.5 minute quadrangle maps